Properties of Fresh Concrete

Introduction

- The potential strength and durability of concrete of a given mix proportion is very dependent on the degree of its compaction.
- It is vital, therefore, that the consistency of the mix be such that the concrete can be transported, placed, and finished sufficiently early enough to attain the expected strength and durability.
Properties of Fresh Concrete

Significance

- The first 48 hours are very important for the performance of the concrete structure.
- It controls the long-term behavior, influence $f'_c$ (ultimate strength), $E_c$ (elastic modulus), creep, and durability.

Elasticity and Strength of Concrete

- The elastic properties of materials are a measure of their resistance to deformation under an applied load (but the elastic strain is recovered when the load is removed).
- Strength usually refers to the maximum stress that a given kind of sample can carry.
- Understanding these properties and how they are measured is essential for anyone wishing to use materials.
Properties of Fresh Concrete

Properties at Early Ages

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

Workability

- Definition: Effort required to manipulate a concrete mixture with a minimum of segregation.

- It is not a fundamental property of concrete.
**Properties of Fresh Concrete**

**Workability**

I) **consistency** (slump) → how easy to flow and

II) **cohesiveness** → tendency to bleed and segregate.

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**Consistency Tests**

**Consistency: Slump Test**

1. Pour the mixture into a measuring cylinder. Record the height of the mixture, then hit the plunger 25 times in 15 seconds. The height of the mixture should be recorded, and the difference in height should be noted.

2. Fill cone with fresh concrete and push the cone up to the plastering tool. Then, pull the cone up to the plastering tool and record the height of the mixture. Subtract the initial height from the final height to get the slump value.

3. Fill cone with fresh concrete and push the cone up to the plastering tool. Then, pull the cone up to the plastering tool and record the height of the mixture. Subtract the initial height from the final height to get the slump value.

4. Place the mixture on the smooth surface of the slab. Measure the average area of the mixture, then record the average area, and subtract the initial area from the final area to get the slump value.
Properties of Fresh Concrete

- The most important properties of fresh concrete are thus associated with its workability and consistency.

- Most concrete must be compacted after it has been placed in the forms.
Properties of Fresh Concrete

- Whether the compaction is achieved by ramming or by vibration, the process consists essentially of the elimination of entrapped air from the concrete until it has achieved as dense a configuration as possible for a given mix.

- Large pockets of entrapped air seriously weaken the concrete since they act as powerful stress concentrators.

Workability

- This term is defined in ASTM C 125 as the property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity.
  - The term manipulate includes the operations of placing, compacting and finishing the concrete.

- Neville and Brooks* define workability as the amount of useful internal work necessary to produce full compaction.
  - They note that the useful internal work is a physical property of the concrete alone, but they note there is additional energy required to overcome friction between the concrete and the formwork and the reinforcement as well as the energy required to vibrate the formwork, the reinforcement, and the concrete which has already been compacted.

- Thus in practice, it is difficult to measure the workability as defined.

Stiffening and Setting

- After completion of mixing, concrete gradually stiffens until it becomes rigid.
- It is essential that it remain plastic long enough to permit being transported, placed, consolidated, and finished.

Setting and Hardening

**Initial Set**: Loss of consistency, unworkable concrete (no less than 45 minutes – ASTM C 150)

**Final Set**: Complete solidification (no more than 375 minutes)
Compacting Factor Tests

- Although there is no generally accepted method of directly measuring workability, Neville and Brooks* point out that probably the best test yet available uses the inverse approach: i.e., the degree of compaction can be measured when a standard amount of work is applied to a standard quantity of concrete.

- The degree of compaction, called the compacting factor, is measured by the density ration which is the ratio of the density actually achieved in the test to the density of the same concrete fully compacted.

- These tests are covered in the United States under ACI 211.3, and in the UK by BS 1881: Part 103: 1983.


The Kelly Ball Test

- Another method used in the field and laboratory to measure the consistency of concrete is the ball penetration test (ASTM C360) which is also known as the Kelly ball test*.

- It is performed by measuring the penetration, in inches, of a 6-in. diameter steel cylinder with a hemispherically shaped bottom, weighing 30 lbs.

- One of the advantages of the ball penetration test can be performed on the concrete in a hopper, buggy, wheelbarrow, or other suitable container.

- Another advantage of this method is its simplicity and the rapidity with which the consistency of the concrete can be determined.

- It is also not dependent on a procedure of filling and rodding a container like the slump test.

Details of the test procedure and the ball-penetration apparatus are given in ASTM C360. There is a direct relationship between slump and ball penetration for a given mix but it varies according to the mix. The ratio of slump to the penetration of the ball is between 1.5 and 2.
The Kelly Ball Test

Pressure Method

- The most common method of measuring the air content of freshly mixed concrete is the "pressure method" (ASTM C231).
- In this method, pressure is applied to a concrete sample placed into an air meter and the reduction in volume observed on a gage calibrated in terms of percent air.
- The observed amount of air includes both the purposely entrained air as well as the entrapped air (about 1% by volume of concrete).
What is sometimes regarded as a need for wetter concrete may be better satisfied by more thorough vibration.

- The use of adequate vibration rather than of a wetter mix will not only insure a more thorough compaction but also the quality of concrete will be superior by not increasing the water content to obtain a greater slump.

- The Careful attention to keeping the mix as dry as possible and being sure that there is adequate vibration will lead to sound concrete.

- The worst combination; however, is to “over” vibrate concrete which is too wet.

  - Excessive care must be taken to prevent this. Heavy structural members and slabs can be satisfactorily placed using a 2-in. slump concrete if it is properly vibrated.
Consistency

- Consistency or fluidity of concrete is an important component of workability and refers in a way to the wetness of the concrete.
- However, it must not be assumed that the wetter the mix the more workable it is. 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.
Workability and Consistency

- In their textbook, Mehta and Monteiro* note that workability is a composite property, with at least two main components:
  
  a. **Consistency** which he describes as the “ease of flow” of the concrete, and
  b. **Cohesiveness** which he describes as the “tendency not to bleed or segregate”.

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Workability and Consistency

- Some of the important factors that affect the workability of concrete are:
  1) relative quantities of paste and aggregates,
  2) plasticity of the paste itself,
  3) maximum size and grading of aggregates, and
  4) shape and surface characteristics of aggregate particles.

- Each of these factors effect the components of workability, consistency and cohesiveness, in different ways.

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**Workability and Consistency**

- Mehta and Polivka* discuss further that:
  - None of the test methods proposed or in use today simultaneously measure all of the properties involved in workability.
  - In practice, the workability of a mix is judged by several properties including consistency, ease of conveying and placing, and lack of segregation or of excessive bleeding.
  - An experienced concrete technician can readily judge when fresh concrete has adequate workability for use in a given situation.


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**Workability and Consistency**

- Mehta and Polivka* go on to say:
  - A concrete mix suitable for massive construction, e.g., of a bridge pier, would not have the required workability for placement in a heavily reinforced column.
  - Thus, a concrete mix should have the needed workability for its intended use. Also, it should not segregate nor bleed excessively.

Workability and Consistency

- Mehta and Polivka* discuss these terms as follows:
  - Workability and consistency of fresh concrete are two closely related properties. Workability is that property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, transported, placed, compacted, and finished.
  - Workability is a property which depends on the specific conditions of placement; a concrete that is workable under some conditions may not be workable under some other conditions.