

Module- 2

FRESH CONCRETE

2.1 There are two sets of criteria that we must consider when making concrete;

- 1) Long-term requirements of hardened concrete, such as, strength, durability, and volume stability,
- 2) Short-term requirements, like workability. However, these two requirements are not necessarily complementary.

2.2 For fresh concrete to be acceptable, it should:

1. Be easily mixed and transported.
2. Be uniform throughout a given batch and between batches.
3. Be of a consistency so that it can fill completely the forms for which it was designed.
4. Have the ability to be compacted without excessive loss of energy.
5. Not segregate during placing and consolidation.
6. Have good finishing characteristics.

2.3 Workability

All the characteristics above describe many different aspects of concrete behavior. The term workability is used to represent all the qualities mentioned. Workability is often defined in terms of the amount of mechanical energy, or work, required to fully compact concrete without segregation. This is important since the final strength is a function of compaction.

The concept of viscosity is a measure of how a material behaves under stress. For a Newtonian fluid, the relationship may be written as:

$$\tau = \eta D$$

Where τ is the shear stress, η is the viscosity, and D is the rate of shear or velocity gradient.

For a very dilute suspension of solids in liquids, this relationship holds true. However, for large volumes of suspended solids, like concrete, the Newtonian model does not work. Concrete has an initial shear strength that must be exceeded before it will flow. This type of behaviour is described by the Bingham model:

$$\tau - \tau_0 = \eta D$$

Where τ_0 is the yield shear stress, η is the plastic viscosity.

A third type of viscous behaviour is called thixotropic, where the apparent viscosity decreases with shear stress. Concrete will exhibit thixotropic characteristics.

2.4 Factors Affecting Workability

- **Water Content of the Mix** -- This is the single most important fact or governing workability of concrete. A group of particles requires a certain amount of water. Water is absorbed on the particle surface, in the volumes between particles, and provides "lubrication" to help the particles move past one another more easily. Therefore, finer particles, necessary for plastic behaviour, require more water. Some side-effects of increased water are loss of strength and possible segregation.
- **Influence of Aggregate Mix Proportions** -- Increasing the proportion of aggregates relative to the cement will decrease the workability of the concrete. Also, any additional fines will require more cement in the mix. An "over sanded" mix will be permeable and less economical. A concrete deficient of fines will be difficult to finish and prone to segregation.
- **Aggregate Properties** -- The ratio of coarse/fine aggregate is not the only factor affecting workability. The gradation and particle size of sands are important. Shape and texture of aggregate will also affect workability. Spherical shaped particles will not have the interaction problems associated with more angular particles. Also, spherical shapes have a low surface/volume ratio, therefore, less cement will be required to coat each particle and more will be available to contribute to the workability of the concrete. Aggregate which is porous will absorb more water leaving less to provide workability. It is important to distinguish between total water content, which includes absorbed water, and free water which is available for improving workability.
- **Time and Temperature** -- In general, increasing temperature will cause an increase in the rate of hydration and evaporation. Both of these effects lead to a loss of workability.
- **Loss of Workability** -- Workability will decrease with time due to several factors; continued slow hydration of C3S and C3A during dormant period, loss of water through evaporation and absorption, increased particle interaction due to the formation of hydration products on the particle surface. Loss of workability is measured as "slump loss" with time.
- **Cement Characteristics** -- Cement characteristics are less important than aggregate properties in determining workability. However, the increased fineness of rapid-hardening cements will result in rapid hydration and increased water requirements, both of which reduce workability.
- **Admixtures** -- In general, air-entraining, water-reducing, and set-retarding admixtures will all improve workability. However, some chemical admixtures will react differently with cements and aggregates and may result in reduced workability.

2.5 Segregation and Bleeding

2.5.1 Segregation refers to a separation of the components of fresh concrete, resulting in a non-uniform mix. This can be seen as a separation of coarse aggregate from the mortar, caused from either the settling of heavy aggregate to the bottom or the separation of the aggregate from the mix due to improper placement.

Some factors that increase segregation are:

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1. Larger maximum particle size (25mm) and proportion of the larger particles.

2. High specific gravity of coarse aggregate.
3. Decrease in the amount of fine particles.
4. Particle shape and texture.
5. Water/cement ratio.

Good handling and placement techniques are most important in prevention of segregation.

2.5.2 Bleeding is defined as the appearance of water on the surface of concrete after it has consolidated but before it is set. Since mixing water is the lightest component of the concrete, this is a special form of segregation. Bleeding is generally the result of aggregates settling into the mix and releasing their mixing water. Some bleeding is normal for good concrete.

However, if bleeding becomes too localized, channels will form resulting in "craters". The upper layers will become too rich in cement with a high w/c ratio causing a weak, porous structure. Salt may crystallize on the surface which will affect bonding with additional lifts of concrete. This formation should always be removed by brushing and washing the surface. Also, water pockets may form under large aggregates and reinforcing bars reducing the bond.

Bleeding may be reduced by:

1. Increasing cement fineness.
2. Increasing the rate of hydration.
3. Using air-entraining admixtures.
4. Reducing the water content.

2.6 Measurement of Workability

Workability, a term applied to many concrete properties, can be adequately measured by three characteristics:

1. Compatibility, the ease with which the concrete can be compacted and air void removed.
2. Mobility, ease with which concrete can flow into forms and around reinforcement.
3. Stability, ability for concrete to remain stable and homogeneous during handling and vibration without excessive segregation.

Different empirical measurements of workability have been developed over the years. None of these tests measure workability in terms of the fundamental properties of concrete. However, the following tests have been developed:

- **Subjective Assessment** -- The oldest way of measuring workability based on the judgement and experience of the engineer. Unfortunately, different people see things, in this case concrete, differently.
- **Slump Test** -- The oldest, most widely used test for determining workability. The device is a hollow cone-shaped mould. The mould is filled in three layers of each volume. Each layer is rodded with a 16mm steel rod 25 times. The mould is then lifted away and the change in the height of the concrete is measured against the mould. The slump test is a measure of the resistance of concrete to flow under its own weight.

There are three classifications of slump; "true" slump, shear slump, and collapse slump. True

slump is a general reduction in height of the mass without any breaking up. Shear slump indicates a lack of cohesion, tends to occur in harsh mixes. This type of result implies the concrete is not suitable for placement. Collapse slump generally indicates a very wet mix. With different aggregates or mix properties, the same slump can be measured for very different concretes.

- **Compaction Test** -- Concrete strength is proportional to its relative density. A test to determine the compaction factor was developed in 1947. It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of a fully compacted volume. This test is difficult to run in the field and is not practical for large aggregates (over 1 in.).
- **Flow Test** -- Measures a concrete's ability to flow under vibration and provides information on its tendency to segregate. There are a number of tests available but none are recognized by ASTM. However, the flow table test described for mortar flows is occasionally used.
- **Remoulding Test** -- Developed to measure the work required to cause concrete not only to flow but also to conform to a new shape.
 - **Vebe Test** - A standard slump cone is cast, the mould removed, and a transparent disk placed on top of the cone. The sample is then vibrated till the disk is completely covered with mortar. The time required for this is called the Vebe time.
 - **Thaulow Drop Table** - Similar to the Vebe test except a cylinder of concrete is remoulded on a drop table. The number of drops to achieve this remoulding is counted.
 - **Penetration Test** -- A measure of the penetration of some indenter into concrete. Only the Kelly ball penetration test is included in the ASTM Standards. The Kelly ball penetration test measures the penetration of a 30 lb. hemisphere into fresh concrete. This test can be performed on concrete in a buggy, open truck, or in form if they are not too narrow. It can be compared to the slump test for a measure of concrete consistency.

2.7 Setting of Concrete

Setting is defined as the onset of rigidity in fresh concrete. Hardening is the development of useable and measurable strength; setting precedes hardening. Both are gradual changes controlled by hydration. Fresh concrete will lose measurable slump before initial set and measurable strength will be achieved after final set.

Setting is controlled by the hydration of C_3S . The period of good workability is during the dormant period, (stage 2). Initial set corresponds to the beginning of stage 3, a period of rapid hydration. Final set is the midpoint of this acceleration phase. A rapid increase in temperature is associated with stage 3 hydration, with a maximum rate at final set.

If large amounts of ettringite rapidly form from C_3A hydration, the setting times will be reduced. Cements with high percentages of C_3A , such as expansive or set-regulated cements, are entirely controlled by ettringite formation.

2.8 Abnormal Setting Behavior

- **False Set** -- Early stiffening of concrete, fluidity may be restored by remixing. Basically, it is a result of hydration of dehydrated gypsum, which forms rigid crystals. Because there are few of these crystals and they are weak, the matrix can be destroyed by remixing. Accelerated hydration of C_3A will cause rapid development of ettringite and false set.
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- **Flash Set** -- Stiffening of concrete due to the rapid development of large quantities of C3A hydration products which cannot be returned to a fluid state with mixing. This is generally no longer a problem since the introduction of gypsum to control C3A hydration. However, some admixtures will increase C3A hydration and flash set may be a problem.

2.9 Tests of Fresh Concrete

1. They permit some estimation of the subsequent behaviour of the hardened concrete.
2. Changes in the properties of fresh concrete imply that the concrete mix is changing, so that some action can be taken if necessary.

Concrete is a composite material made from cement, aggregate, water, and admixtures. The variation of these components both in quality and quantity directly affects the resulting mix. When sampling fresh concrete for testing, it is important to take samples from various locations or several points during the discharge of the concrete. Samples should not have contacted forms or subgrade, and collection should be done in such a way that no segregation occurs.

- **Time of Setting** -- A penetration test, used to help regulate the times of mixing and transit, gauges the effectiveness of various set-controlling admixtures, and help plan finishing operations. The test is performed on the mortar fraction, the amount of concrete passing a No. 4 sieve, of the concrete rodded into a container.
- **Air Content** -- These tests measure the total air content, entrained air plus entrapped air expressed in terms of the volume of concrete.
 - **Gravimetric Method** -- Compares the weight of a concrete containing air to that of a computed air-free concrete.
 - **Volumetric Method** -- Compares the volume of fresh concrete containing air with a volume of the same concrete after the air has been expelled by agitating the concrete under water. Difficult to measure in the field and required a large amount of physical effort.
 - **Pressure Method** -- The most common field measurement for air content. Compares the change in volume of a concrete under a given pressure. This change in volume is caused entirely by the compression of air in the concrete, both in the cement and the aggregate.

*** All these tests give no information about the spacing of the voids. They only measure the total air content of the concrete.

2.10 Unit Weight and Yield

The unit weight of fresh concrete can be determined by weighing a known volume. This is usually performed just before air content is determined since there is known volume concrete. The volume of a batch of concrete can be determined from the following relationship:

$$V = \frac{w}{\text{Unit weight}} (ft^3)$$

Where, **w** is the weight of the concrete components, including water.

The yield of a concrete mix can be determined from:

$$Y = \frac{V}{W_{\text{cement}}} \left(\frac{f+3}{lb} \right)$$

Where, W_{cement} is the weight of the cement for a given mix.

2.11 Rapid Analysis of Fresh Concrete

There are a number of tests which separate the components of fresh concrete and test for a variety of mix properties; however, none are as yet accepted by ASTM. There are some tests that do not require separation of the components of the concrete:

- **Thermal Conductivity** -- Increase in water slows temperature rise.
 - **Capacitance Test** -- Higher water content, increases dielectric constant.
 - **Electrical Resistance** -- Electrical resistance of fresh concrete is inversely proportional to the water content.
 - **Nuclear Methods** -- X-rays, gamma-rays, and neutron activation analysis can be used to measure the cement and water contents.
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