Topic 4 Concrete

What is Grade of Concrete?

Grade of concrete is defined as the minimum strength the concrete must posses after 28 days of construction with proper quality control. Grade of concrete is denoted by prefixing M to the desired strength in MPa. For example, for a grade of concrete with 20 MPa strength, it will be denoted by M20, where M stands for Mix. These grade of concrete is converted into various mix proportions. For example, for M20 concrete, mix proportion will be 1:1.5:3 for cement: sand: coarse aggregates.

Grade of concrete construction is selected based on structural design requirements. There are two types of concrete mixes, nominal mix and design mix. Nominal mix concrete are those which are generally used for small scale construction and small residential buildings where concrete consumption is not high. Nominal mix takes care of factor of safety against various quality control problems generally occurring during concrete construction. Design mix concrete are those for which mix proportions are obtained from various lab tests. Use of design mix concrete requires good quality control during material selection, mixing, transportation and placement of concrete. This concrete offers mix proportions based on locally available material and offers economy in construction if large scale concrete construction is carried out. Thus, large concrete construction projects use design mix concrete. So, suitable grade of concrete can be selected based on structural requirements. Nominal mixes for grades of concrete such as M15, M20, M25 are generally used for small scale construction. Large structures have high strength requirements, thus they go for higher grades of concrete such as M30 and above. The mix proportions of these concretes are based on mix design.

Concrete Grade	**Mix Ratio**	**Compressive Strength MPa (N/mm^2)**
Normal Grade of Concrete		
M5	1 : 5 : 10	5 MPa
M7.5	1 : 4 : 8	7.5 MPa
M10	1 : 3 : 6	10 MPa
M15	1 : 2 : 4	15 MPa
M20	1 : 1.5 : 3	20 MPa
Standard Grade of Concrete		
M25	1 : 1 : 2	25 MPa
M30	Design Mix	30 MPa
M35	Design Mix	35 MPa
M40	Design Mix	40 MPa
M45	Design Mix	45 MPa
High Strength Concrete Grades		
M50	Design Mix	50 MPa
M55	Design Mix	55 MPa
M60	Design Mix	60 MPa
M65	Design Mix	65 MPa
M70	Design Mix	70 MPa

What are the Proper Concrete Mix Proportions?

Proportioning of concrete is the process of selecting quantity of cement, sand, coarse aggregate and water in concrete to obtain desired strength and quality. The proportions of coarse aggregate, cement and water should be such that the resulting concrete has the following properties:

1. When concrete is fresh, it should have enough workability so that it can be placed in the formwork economically.
2. The concrete must possess maximum density or in the other words, it should be strongest and most water-tight.
3. The cost of materials and labour required to form concrete should be minimum.

The determination of the proportions of cement, aggregates and water to obtain the required strengths shall be made as follows:

1. By designing the concrete mix, such concrete shall be called design mix concrete.
2. By adopting nominal mix, such concrete shall be called nominal mix concrete.

Ingredients

Cement

An adhesive, the principal ingredient in cement is calcium oxide. Calcium oxide is a product of superheated limestone. Cement also has silicon, aluminum, iron, and a variety of other secondary ingredients. Cement is the bonding agent that holds the aggregate and sand of concrete together once it cures.

While very hard, the strength of cured cement does not compare to that of rock and sand. As such, cement is the reason concrete has weak tensile strength and requires rebar. Torque can easily break concrete. That is because concrete relies on the strength of the cement to resist torque.

It is important to remember, more cement does not mean greater compressive strength, it means better adhesion. The two are not synonymous.

Aggregate

Washed, crushed rock — often mistakenly called gravel — aggregate is the component that gives concrete its compressive structural integrity. Concrete has tremendous compressive strength. The rocks and sand support the concrete when it is being compressed.

Sand

Not only the filling agent that eliminates air pockets and spaces between the individual crushed rocks, sand also has a very high compressive strength.

Water

Water creates the chemical change in the quicklime of cement that makes it adhere to rock and sand, water also makes concrete workable. Without water, mixing, forming, and finishing concrete is not possible

Concrete Mix Proportions Notes to Remember

1. The more rock, the greater the compressive strength of concrete. The more sand, the greater the workability.
2. Adhesion (cement) and compressive strength (rock) are two different factors in the quality of concrete. More cement does not mean more compressive strength; it means more tensile strength.
3. The less water, the stronger the adhesion of cement, but the more difficult it is to work with the concrete.

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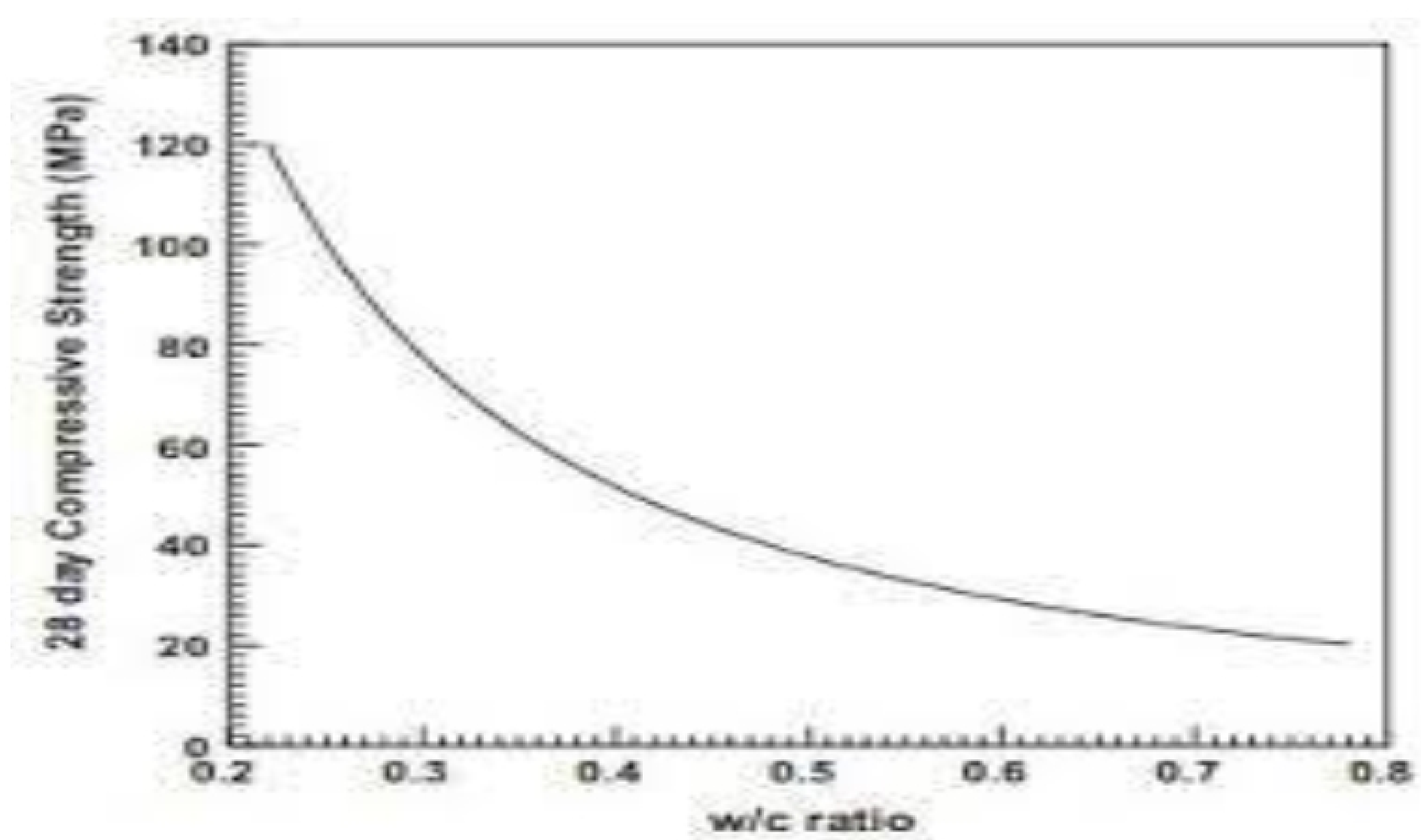
WHAT IS WATER CEMENT RATIO?

The water–cement ratio is the ratio of the weight of water to the weight of cement used in a concrete mix. A lower ratio leads to higher strength and durability, but may make the mix difficult to work with and form. Workability can be resolved with the use of plasticizers or super-plasticizers.



Concrete hardens as a result of the chemical reaction between cement and water (known as hydration, this produces heat and is called the heat of hydration). For every kilogram or any unit of weight of cement, about 0.35 kg or corresponding unit of water is needed to fully complete hydration reactions.

However, a mix with a ratio of 0.35 may not mix thoroughly, and may not flow well enough to be placed. More water is therefore used than is technically necessary to react with cement. Water–cement ratios of **0.4 to 0.60 are more typically used.** For higher-strength concrete, lower ratios are used, along with a plasticizer to increase flow ability.

Too much water will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave concrete as it hardens, resulting in microscopic pores (bleeding) that will reduce final strength of concrete. **A mix with too much water** will experience more shrinkage as excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners), which again **will reduce the final strength.**

There are two sets of criteria that we must consider when making concrete.
Long-term requirements of hardened concrete, such as, strength, durability, and volume stability.
Short-term requirements, like workability. However, these two requirements are not necessarily complementary.
This chapter deals only with the short term requirements. 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.

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.

Factors Affecting Workability

1. **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 behavior, require more water. Some side-effects of increased water are loss of strength and possible segregation.

2. **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 "oversanded" mix will be permeable and less economical. A concrete deficient of fines will be difficult to finish and prone to segregation.

3. **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.

4. **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.

5. **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.

6. **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.

Segregation and Bleeding

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:

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.

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 crystalize 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.

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 mold. The mold is filled in three layers of each volume. Each layer is rodded with a 16mm steel rod 25 times. The mold is then lifted away and the change in the height of the concrete is measured against the mold.
The slump test is a measure of the resistance of concrete to flow under it 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 concretes 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.

Remolding 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 mold 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.

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.