Building Materials III
Lecture 3

Cement Concrete

Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement which hardens over time. We talked about the various materials that go into making concrete and how it is done. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements. As I said, there are various other types of cement which can go into the making of concrete. The most basic of them being, Portland cement which is used widely. In Portland cement concrete and other hydraulic cement concretes for that matter, when the aggregate is mixed together with dry cement and water, they form a fluid mass that is easily molded into shape. We talked about cement that acts as the binding material, water which initiates the binding reaction and the course materials and the fine materials that are added together to form the composite material. This is what concrete is. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. The basic form of construction material, the basic form of construction unit - concrete, this is how it is formed. Going a little into the famous uses of concrete which are from the last few centuries. Our famous concrete structures include the Hoover Dam, the Panama Canal and the Roman Pantheon. We talked about Pantheon and how its dome is made of concrete. The earliest large-scale users of concrete technology were the ancient Romans. The Colosseum in Rome was built largely of concrete, and the concrete dome of the Pantheon is the world's largest unreinforced concrete dome. Not only did they use concrete, it is also unreinforced. The shape of the dome, the strength and its character is such that it doesn't need any reinforcement. Concrete is a composite man-made material, it is the most widely used building material in the construction industry. In Fact the most widely used material after water is concrete. Freshly mixed concrete before set is known as wet or green concrete whereas after setting and hardening it is known as set or hardened concrete. Concrete when mixed with water and other aggregates to form concrete, is called as green or wet concrete. This is basic concrete which is used for workability. The resulting concrete which is hardened and set is called hardened concrete.

We move on to the properties of concrete which give its unique characteristics - Concrete has relatively high compressive strength but significantly lower tensile strength. The most worthwhile aspect or property of concrete is its high compressive strength. Even though the low tensile strength is present, it can be altered by varying the cements and aggregates or with the help of reinforcement and as such is usually reinforced with materials that are strong in tension. As I said, reinforcements can be used to increase the tensile strength and also the

compressive strength for that matter. The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. There are various things that concrete undergo after being set. We will discuss about it in detail and how it can be affected and varied.

Concrete has a very low coefficient of thermal expansion and as it matures, concrete shrinks. All concrete structures will crack to some extent. Cracking is not something that can be avoided but the extent to which it cracks is something that can be controlled and beneficial as well. It will crack to some extent due to shrinkage and tension. When you are adding a chemically sound subject like cement to coarse aggregates and fine aggregates with that of water, a lot of reactions happen. This results in tension and shrinkage and obviously some crack happens to a certain extent. Concrete which is subjected to long duration forces is prone to creep.

The properties of concrete in brief - Grades. Grading of concrete is an important property from which we choose the type of concrete that is required for the particular type of construction. The compressive strength, the characteristic strength, the tensile strength, these are the other three important factors. The durability of concrete, this infact is the most important property and is a property that has developed over the years.

Creep, Shrinkage, Unit Weight, Modular Ratio and Poisson's Ratio; these are all resultant reactions that happen after a concrete is set. We will look at these properties in detail.

Grading - Concrete is known by its grade which is designated as M15 and M20. When you refer to concrete at a construction site, the way it's referred to is in terms of M, which is nothing but a reference to the specified compressive strength of 150mm cube at 28 days. This is a particular measurement, such that concrete can be classified into M15 and M20. If you actually look at it, M20 and M25 are the most common grades of concrete, and higher grades of concrete should be used for severe, very severe and extreme environments. These are grades that denote the compressive strengths. For domestic and construction purposes, M20 and M25 are more than feasible but if you are going in for higher cases like bridges, runways at airports, you need more higher grades of concrete.

That was grading, we will now look into Compressive strength. Like load, the strength of the concrete is also a quality which varies considerably for the same concrete mix. Therefore, a single representative value known as characteristic strength is used. Thoroughly, overall for the batch, we use a characteristic called the compressive strength of concrete. Under Compressive Strength, we have the characteristics of concrete - it is defined as the value of strength below

which not more than 5% of the test results are expected to fall (i.e there is 95% probability of achieving this value and only 5% of not achieving the same.)

Creep in concrete - Creep is defined as the plastic deformation under sustain load. There is plasticity that happens when concrete is being made or set. The plastic deformation under sustained loads is called creep. Creep strain depends primarily on the duration of sustained loading. According to the code, the value of the ultimate creep coefficient is taken as 1.6 at 28 days of loading. 28 days is actually a curing time. Every aspect of concrete setting and concrete curing is based on these 28 days and this is used as a measuring mode.

Shrinkage of concrete - The property of diminishing n volume during the process of drying and hardening is termed Shrinkage. It depends mainly on the duration of exposure. If this strain is prevented, it produces tensile stress in the concrete and hence concrete develops cracks.

The process of relative proportions of cement, sand, coarse aggregate and water, so as to obtain a concrete of desired quality is known as the proportioning of concrete. We looked at properties, the main factor or main ingredient that goes into this is the proportioning of the various materials that go into making. This is called the proportioning of concrete, this is the most basic factor of making concrete. The proportions should be such that the resulting concrete has the following properties - When concrete is fresh, it should have enough workability so that it can be placed in the formwork economically. Workability is the most basic form of using concrete, that has to be maintained.

The concrete must possess maximum density or in other words, it should be the strongest and most water-tight. Another important factor. The cost of materials and labour required to form concrete should be minimum. This is another economical factor apart from the reactions.

The determination of the proportions of cement aggregates and water to obtain the required strengths shall be made as follows - By designing the concrete mix, such concrete shall be called design mix concrete or By adopting nominal mix, such concrete shall be called nominal mix concrete. Design mix concrete is preferred to nominal mix. Concrete of each grade shall be analyzed separately to determine its standard deviation. There is a particular way of looking at it. Design mix concrete and Nominal mix concrete. Designing the concrete mix such that the concrete shall be called design mix concrete or by adopting nominal mix, such that the concrete shall be called nominal mix concrete. These are the two mixes for proportioning of concrete. Design mix concrete is preferred to nominal mix. Basically if you had to refer or go through researches of concrete making, Design mix is the most used form. Concrete of each grade shall be analyzed separately to determine its standard deviation.

A thumb rule that is widely followed in domestic architecture. The jungle expression for the proportions of cement, sand and coarse aggregate is 1n:2n by volume. Standard mixes are 1:1:2 and 1:1.2:2.4 for every high strength. 1:1.5:3 and 1:2:4 for normal works. 1:3:6 and 1:4:8 for foundations and mass concrete works.

Another way of proportioning is the Fineness Modulus Method - the term fineness modulus is used to indicate an index number which is roughly proportional to the average size of the particle in the entire quantity of aggregates. The fineness modulus is obtained by adding the percentage of weight of the material retained on the following sieve and divided by 100. The courses the aggregates, the higher the fineness modulus.

Other ways of proportioning and how it affects the characteristics of Water Cement Ratio - We talked about the ratio of the overall aggregates in water. The particular ratio of water and cement alone can have various different impacts. The single most important indicator of strength is the ratio of the water used compared to the amount of cement (w/c ratio). Basically, the lower this ratio is, the higher the final concrete strength will be. This concept was developed by Duff Abrams of the Portland Cement Association in the early 1920s and is in worldwide use today. A minimum w/c ratio (water-to-cement ratio) of about 0.3 by weight is necessary to ensure that the water comes into contact with all the cement particles. Thus, assuring complete hydration. This water cement ratio is a direct effect on the strength of concrete. A lower ratio leads to higher strength and durability but may make the mix difficult to work with and form. Workability which we talked about, becomes difficult when the water cement ratio is higher. 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). Too much water will result in segregation of the sand and aggregate components from the cement paste. It becomes a little bit too plastic. 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. Pores or capillaries are formed which reduce the direct final impact of concrete strength.

Advantages of low water/cement ratio. As I said, water/cement ratio has to be maintained to some extent but varying it to its increase or decrease has its own advantages. In this case, low water/cement ratio can yield increased strength, lower permeability, increased resistance to weathering, increased resistance to weathering, better bond between concrete and reinforcement, reduced drying shrinkage and cracking and less volume change from wetting and drying. The stage from wetting, curing and drying happens over a period of time. This volume change can be reduced.

Cement Workability & Curing

Workability is nothing but the property of freshly mixed concrete that determines its working characteristics, i.e the ease with which it can be mixed, placed, compacted and finished. This is what we do basically to concrete. We mix it, we place it, we compact it and we finish it. This is called as the workability. Workability is the most important working form in terms of concrete and is affected by various factors. The factors affecting workability - Method and duration of transportation. Transportation does not necessarily mean from one place to another. Cement concrete is made in one place, the transportation from ground floor to first floor or ground floor to 10th floor can have an affect on the workability. The quantity and characteristics of cementing materials, Concrete consistency (slump), Aggregate grading, shape and surface texture, the Percentage of entrained air, Water content, Concrete and ambient air temperature and Admixtures. These are factors that affect workability. The single most nature of workable concrete is its lubricating nature. What makes workability happen is the reaction or the lubrication between these particles. If a concrete shows more lubricating nature, then it will have the following advantages, such as - it will exhibit little internal friction between particles. What happens is, when cement hardens, if it hardens too quickly, internal friction will be more. Let's say workability of concrete is much better, this is reduced. It will overcome the frictional resistance offered by the surface of the formwork and reinforcement contained in the concrete. When you place concrete, lots of formworks are used, the friction between formwork and the actual concrete can be reduced in case of better workability. It can be consolidated with minimum compacting effort. Compacting effort is an important thing in order to set concrete, this can be made better with workability. Water content and aggregate cement ratio is an important factor that affects workability. Workability of concrete increases with increase in water content. Water being added more in quantity will increase the plasticity, the binding nature and thus increase the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability.

Aggregate/Cement Ratio - the higher the aggregate/cement ratio, the learner is the concrete. Having a leaner concrete, helps in having a strong concrete. In lean concrete, less quantity of paste is available for providing lubrication, hence mobility of aggregate is reduced, resulting poor workability. But in case of lower aggregate/cement ratio, the richer is the concrete. In rich concrete, more paste is available to make the mix cohesive and fatty to give better workability.

Now we come to Curing. Curing is the final process which actually sets the concrete. Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This is done via various methods but this is basically the basis

behind the method. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks, which can severely affect durability. A concrete element is expected to last a certain number of years. Why do we construct? We need the building to last a certain number of years. The main factor that affects that is curing. In order to meet this expected service life, it must be able to withstand structural loading, fatigue, weathering, abrasion and chemical attack. The duration and type of curing plays a big role in determining the required materials necessary to achieve the high level of quality. As I said, Curing actually determines the lifespan of the building. This is how curing is done, you must have seen it. Now you'd be able to recognize what it is. There are various methods of curing. The adoption of a particular method will depend upon the nature of work and the climatic conditions. Curing requires the modifying of the temperature and the exposure of the cement setting, the concrete setting. The nature of the climate condition matters, the following methods of curing of concrete are generally adopted - Shading concrete work. Covering concrete surfaces with hessian or gunny bags, Sprinkling of water, Ponding method, Membrane curing and Steam curing. We will talk about two or three types -

Sprinkling of water: Just splashing water over the concrete setting, which is water continuously on the concrete surface providing an efficient curing. When you lay floor slabs with concrete, you cure it by sprinkling water, concrete should be able to set sufficiently before sprinkling is started. The spray can be obtained from a perforated plastic box. On small jobs, sprinkling of water may be done by hand. Vertical and sloping surfaces can be kept continuously wet by sprinkling water on top surfaces and allowing it to run down between the forms and the concrete. For this method of curing the water requirement is higher. Curing obviously requires a lot of water, we talked about the three phases in which water is required, curing being the final and most important.

Ponding method, a very efficient method. In fact, the best method of curing. It is suitable for curing horizontal surfaces such as floors, roof slabs, road and airfield pavements. The horizontal top surfaces of beams can also be ponded. After placing the concrete, its exposed surface is first covered with moist hessian or canvas. After 24 hours, these covers are removed and small ponds of clay or sand are built across and along the pavements. You have them built on edges and then form separate lines to create smaller ponds. The area is thus divided into a number of rectangles. The water is filled between the ponds. The filling of water in these ponds are done twice or thrice a day, depending upon the atmospheric conditions. The atmospheric conditions play an important role in curing. Accordingly, two or three times it is done.Though this method is very efficient, the water requirement is very heavy.

Guniting & Water Proofing

Guniting is a type of spraying concrete, it is used for repairing and other purposes. Gunite or Shotcrete is a product developed as a solution for tunnels underground structures, slope stabilization, structural repairs and pools. Gunite is a mortar that is sprayed pneumatically onto surfaces at a high velocity. Spraying concrete mortar is guniting. Gunite or shotcrete material is mortar or small aggregate concrete applied using a wet or dry process. Blowing or pneumatically spraying concrete, either in a wet or dry manner, it is called Guniting. These are the basic two types of Guniting. Once gunite has been applied it starts a simultaneous process of consolidation and settling. Guniting as you can see is sprayed and cement concrete spraying is largely used in the case of swimming pools.

Gunite offers some advantages over traditional concrete. It will be placed and consolidated at the same time. Gunite normally has a maximum aggregate size of 3/8", which helps improve quality and improves manageability. Shotcrete will adhere to surfaces better than regular concrete. Shotcrete can be used with steel fiber that will be used as a replacement of welded wire mesh. When steel fibers are used in shotcrete, better flexural strength, ductility and toughness are obtained. It generally offers lower costs when compared to traditional concrete. It offers reduced shrinkage and lower permeability.

Guniting can aid in the following applications - Slope stabilization, Dome Construction, Tunneling, Retention walls, Water tanks and pools, Artificial ponds, Ditches and Channels, Structural reinforcement, Mining applications, Dikes and Dams. As mentioned earlier, there are two types of shotcrete method - the dry method shotcrete method is used when ingredients are placed into a hopper and then pushed out pneumatically through a hose to the nozzle. The nozzle man or the certified operator then controls the addition of water at the nozzle that would eventually be combined once the material hits the surface. Wet-mix shotcrete is the type of application that normally uses prepared concrete or ready-mixed concrete. Compressed air is then applied at the nozzle to propel the wet mixture over the receiving surface. This is the most commonly used process as it produces less rebound and dust compound to a dry-mix process. The greatest advantage of the wet-mix process is that larger volumes can be placed in less time. In case of water or moisture exposed spaces, this is a better way of doing it.

Water proofing - an important characteristic because obviously moisture or water exposure is a lot in various climates. The following waterproofing methods are commonly used in construction - Cementitious waterproofing, Liquid Waterproofing Membrane, Bituminous Membrane, Bituminous Coating and Polyurethane Liquid Membrane. The most common type of waterproofing is Cementious waterproofing and Liquid waterproofing. You can see how it is done in this picture, this is bituminous type of coating, this is done for a more expensive more efficient requirement of coating.

Types of concrete - Concrete can be varied in various ways; addition of aggregates, in the way the hardening takes place, in the way the curing takes place. Accordingly, it can be classified into different types - Lightweight concrete, Aerated concrete, No fines concrete, Fiber reinforced concrete, Reinforced cement concrete, Pre-stressed concrete and Mass concrete. We will briefly look at what these concretes are. Lightweight concrete is a type of concrete made using lightweight aggregates and is favourable for a lot of conditions. Aerated concrete is produced by including air or slurry in a concrete. No fines concrete is a type of concrete that does not include fine aggregates. Fiber reinforced concrete which is rather an expensive method but very important in research and advancement for the future. It is actually the increase in the elasticity of concrete, by reinforcing with natural or artificial fibers. Reinforced cement concrete is the most common or important form of construction method. Concrete in itself is good when it's set but reinforcing it with steel increases its compressive strength. So, imposing it with steel bars is an important way of doing it. Reinforced cement concrete is the result. Pre stressed concrete - concrete other than being formed on site, can also be cast earlier in factories and then being brought to site and fitted directly. This is called as pre-stressed. Prestressed can be pre cast, pre stressed or stressed after being warmed. There are various methods. Mass concrete is nothing but concrete at a massive level. It is different in the aspect, when you use massive amounts of concrete making, the results, the reactions are massive. It's required conditions, its characteristics are varied. It is also a different type of concrete when compared to the normal type of concrete.