Concrete Engineering and Technology
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Lecture - 39
Laboratory Demonstration

(Refer Slide Time: 00:27)

As the first part of the discussion today, let us take up the materials; that we use in normal concrete construction. This here is some of the naturally occurring coarse aggregates. You will notice that the edges of all these aggregates are round and they are all of different sizes. So, we get a particle size distribution of these coarse aggregates; some of which may be smaller, some of which may be larger and so on. So, in contrast to this naturally occurring coarse aggregate, we have crushed stone as coarse aggregates.

Now, these aggregates are prepared by crushing naturally occurring rock, and again these two are of different sizes; and they have sharp edges, because when we manufacture them by crushing the rock, we get this sharp edges in contrast, naturally occurring aggregates have been rounded by the action of natural forces such as, wind or water and so on.

Now, if you look at another sample of coarse aggregates, which is this. We see that these aggregates are largely smaller than this. So in order that, we get a particular particle size distribution for a particular concrete, we need to mix the aggregates, which may have this particle size distribution and some aggregates, which have this particle size distribution, which would obviously on the larger size. It is not very common to mix natural aggregates and crush zone.

(Refer Slide Time: 02:15)

Now, let us look at some samples of fine aggregate. This is one set of fine aggregates, which is what we will use as or what we can sand compare to this, we have another sample of sand, which look something like this. And if we look at this, even by the look and test the field, we know that this sand is coarser than this sand, depending on the application that we have in mind, we use the coarser sand or the finer sand.

The finest modulus of these two sands is different; The finest modulus which is a single parameter for representing the fineness or the particle size distribution of fine aggregate, this sand will have a fineness modulus of about 2.2, 2.3. Whereas this sand, which is finer will have a fineness modulus of about 1.1, 1.2 or something like that. This is the sand, which we often use in our plastering application; this is the sand, which we generally use for concrete.

Now, we come to the most important and perhaps most expensive of, the construction materials in concrete and that is cement. So this is ordinary Portland cement; that is the one that, we use for most of our concrete construction, may be in mortar plaster and so on and so forth its grain color is very fine and we will need to study its properties in great detail, before we can actually use it. And lastly, this is water, which provides the basic ingredients for the hydration of cement.

Now, we come to the additional material; that is used in concrete other than the coarse aggregate, fine aggregates, cement and water. First of all, let us look at fly ash, which is used as a substitute of cement. So there are different kinds of fly ash; which may be looking different but, they are looking very fine powders and the fineness is comparable to that of cement.

As, we have fly ash there is also silica fume, and if you look at silica fume, this what it looks like this powder is difficult to see but, if you have a chance, please take a look and you will realize that, the fineness of this powder is much higher. Typically silica fume has the fineness of about 1/10 of normal cement.

Now, what we do this cements is that either we can mix the cement and the pozzolanic material at the cement plant, what we get is the pozzolanic Portland cement? that is a cement in, which the ordinary cement or the ordinary Portland cement has been premixed, which something like fly ash at different levels of replacement may be 10 percent, 15 percent or whatever to produce PPC or pozzolanic Portland cement other varieties of cement are also available in the market; for example, this is white cement.

Now, how do we get white cement as against the normal grey colored ordinary Portland cement? is something, which I would like to leave as an assignment, there is some process, that is required to choose the raw materials carefully. So that, what we get is white cement, that is does not have the grey color.

Continuing our discussion with special materials or materials, in addition to those use the normal concrete construction. Let us take a look at, a sand substitute this material here in copper slag; it is a byproduct from the copper industry and the idea is, that given its fineness, it does not qualify as a cement substitute.

However, it can very well be used as a sand substitute, compare the properties of this copper slag with the properties of sand, which we saw earlier there are differences but there is a logical basis to believe, that this material which is copper slag, can be used as a substitute for normal sand, at least in concrete construction given the fineness of this material, it may not be possible to use it as a substitute for very fine sand.

So, we have to go through the same tests as, we go for normal sand determination of fineness modulus, determination of water absorption and so on. And decide, whether we can use copper slag or not? and how much of copper slag can be used without effecting the properties of concrete?

Let us look at, another sand substitute this is again recycled sand but, that produced from crushed concrete, recycled concrete, concrete structures, which have been demolished and so on. Give us demolished concrete or waste concrete, waste hardened concrete now; that concrete if it is crushed gives us something like this, and this again is a possible option against the naturally occurring sand. The naturally occurring sand, is becoming more and more of a pressures commodity and we must ensure as, concrete engineers to have a sustainable concrete; that is concrete, which relies less and less on natural materials.

So, if we can find substitutes the better, it is crust concrete also gives us larger size particles as shown here, and on the face of it, and they can be used as a substitute for crushed stone and coarse aggregates. So, look the coarse aggregates here and look at the recycled aggregates, here there is a difference but, yes they can be used at least in certain applications and the challenge is to identify the proper applications or the applications, where we can use this kind of recycled material rather than using virgin coarse aggregate, which is shown here.

So, recycled concrete gives us an option in terms of coarse aggregates, which have a certain size distribution and also fine aggregates, which has another précised distribution much smaller and this is, what is comparable to sand? And this is, what is comparable to coarse aggregates? Notice that, recycles aggregate is different from naturally occurring aggregates. Recycled aggregate often has mortar is sticking to the surface of old aggregates; sometimes we have old aggregates, which also has a coating of cement paste or mortar and sometimes particles of mortar or portions of mortar head here to the coarse aggregates.

What happens is the result of this adhesion of mortar, in the case of recycled aggregates? is that the water absorption of these coarse aggregates increases in the properties of the concrete; that we get if we use recycled concrete as coarse aggregate, will be different in terms of strength and so on. Because there strength of these aggregate in certain sense is lower than the strength of these crust stones.

Other than mineral admixtures, we said that we use chemical admixtures in concrete; now these chemical admixtures, which is shown here are usually available as fluids and they can serve the purpose of air entrainment water reduction, retardation, acceleration and so on. And so forth depending on, what chemicals actually go into making this kind of a liquid.

As far as, using this admixture in concrete is concerned; we have discussed that these admixtures are measured endorsed in term of cement percentage. We take a precise volume of the chemical admixture and diluted with water, and this water now is properly measured again and used as a part of the mixing water. So we rarely use chemical admixtures in the concentrate form but, we use them in a diluted form. We do a an appropriate dilution and use the diluted chemical admixture, as part of the mixing water, this ensures a better distribution throughout the concrete mass.

At, another additional material or material other than the normal materials, that we use in concrete construction. Sometimes is fibers and these fibers if you see here, these are steel fibers; these fibers can be of different shapes; they need not be crimped like this, they could be bent at the edges like this or they can have different diameters, different length and so on. And depending on the kind of fiber that we want to use. We need to carryout studies to determine, what is the kind of mix proportion; that we will need to use.

This steel is not the only material; that is used for fibers. We sometimes use glass fibers; these are glass fibers, you will notice that they are much shorter, at least the sample. That I am showing you is much shorter than the steel sample, that we saw just now.

Other than glass, we also use polypropylene fibers, which is being shown here; now these fibers are with again very difficult to work with as far as, the ability to mix in concrete is concerned. We will study about the properties of steel fiber or glass fiber reinforced concrete subsequently but, please remember that all these fibers, whether they are polypropylene or glass or steel, different shapes, different sizes, different diameters, different lengths; they all need to be mixed in concrete and therefore, we have to ensure that their distribution throughout the matrix is homogeneous.

Any discussion on concrete construction is not complete, unless we talk about the reinforcing material, as well this here is the normal m s bar or mild steel rod of a certain diameter in contrast to this; we have these bars, which are of different diameters may be something like this, which is smaller then there are bars, which are bigger something like this or something like this b.

Now, these steel bars go to reinforce the concrete be weak in tension, what we use in reinforce concrete, is steel as a reinforcing material and you will notice that, these bars have ribs on the surface and these ribs help to increase the bond strength of the concrete, and the steel bar; now these bars are susceptible to corrosion, that is over a period of time. Even if they are embedded in concrete, they will corrode and as one of the corrosion resistant measure, that we use is to use epoxy coated bars; that is something like this and here we will see that; it is nothing but, a normal steel bar except that, it has a coating on the surface; and this coating of epoxy on the surface of steel helps, prevent any direct contact between the atmosphere and the steel and therefore, the life of this steel bar is much longer than that of normal steel bars. Of course, they become a little more expensive than the steel bars.

Apart from epoxy coated bars, which are at the end of its steel. We also use non corrosive materials such as, fiber reinforce plastics; and these are now available as alternative reinforcing materials to be used in reinforce concrete or pre-stressed concrete construction. Since, they are manufactured as an engineering product. We can actually change the properties, the shape, and so on of the fiber reinforce plastic. The fiber again in this case, could be glass it could be carbon, it could be aramid, and so on. And they are available in different shapes and sizes.

For example: this here is a round bar, this here is a flat; these also fiber reinforce, it is a fiber reinforce plastic and is available for reinforcement of concrete construction, except that in this in these two cases, we can notice that there is no corrugation or a mechanism, by which we can increase the bond between the reinforcing material, which in this cases the fiber reinforcing plastic or the fiber reinforce plastic and the surrounding concrete.

This is a sample of the long strand of glass fiber, and we saw the shorthand version of this. When we saw the short glass fibers, so these long glass fibers can be used and in fact, they are used to manufacture glass fiber reinforced plastic rods, which could be of this shape finally, and on this bar you would notice, that there are corrugations to improve the bond between the concrete and the reinforcing material.

Another way of improving, the bond between the reinforcing material and the fiber reinforce plastics could be sand deposits, so we make some effort and deposit sand or create roughness on the surface of the bar, so that we get a better bond between the reinforcing material and the surrounding concrete. Continuing our discussion, with the epoxy coated bars; we know that in certain cases the bars need to be bent at site, which is shown here. And this is a bent epoxy coated bar and we should be careful. When we are using such bars to make sure that, there are no cracks on the coating. Because once, we coat the bar and bend it, the outsides surface here is subjected to tension and the coating is likely to crack, unless it has a sufficient amount of deformability.

This is another variety of steel, being used in concrete construction and is a strand, which we use in pre-stress concrete construction. So if we look at the cross section here, this has 7 individuals strands like this, which are woven into a single strand, these are 7 wires. If you want to call them, woven into a single strand and this is, what is used as a reinforcing material in problem-stress concrete construction.

Since, fiber reinforce concretes are made in the factory, to conform to whatever kind of properties, we want by controlling the volume of fiber, the type of epoxy, that we use the type of fiber itself, we calculate get them in different forms.

For example: These are carbon fiber woven fabric; a similar fabric is a random mat in carbon fibers like this. In a unidirectional carbon fiber fabrics, all the fibers are aligned in one direction, in a case of a woven fabric, which is like this they are aligned in both directions. So we get reinforcement action in both sides in this case, we get reinforcement action only in the one side; that is the direction in which the fibers are aligned.

Different uses of all these materials, in terms of the fabric or in terms of the fiber reinforce plastic rods or flats are being discovered, are being used in order that the concrete construction, becomes more durable. Use of fiber reinforce plastics in normal reinforce concrete construction is still a far dream; they are costly materials but, yes engineers are willing to use them in special applications, where we want durable construction, which should be free from any risk of corrosion of the reinforcing bars.

Now, one of the things that we need to bother about, is techniques shape of the aggregates. So this is the normal aggregate or crust stone, which is used as aggregate which we saw, you will notice that by and large, these aggregates are cuboids; that is the 3 dimensions are more or less. Similar we have to be careful, that we do not have too many particles, which are like this, which have 1 dimension which is longer than the other two and that part is controlled by determining, what is called the elongation index.

So, we here we see some of these particles, which are elongated; that is 1 dimension is larger than the other two in comparisons, to this we have some other problem in comparisons to these aggregates are flaky; that is 1 dimension is much smaller than the other two and both elongated particles and flaky particles cannot be used in concrete construction, they should not be used in concrete construction. We cannot avoid them and therefore, usually what this specification say is that once, we have an aggregate sample, we determine the elongation index and the flakiness index and it should be within a certain permissible number.

We may mix some of these aggregates, which could be or perhaps flaky something like this but, there should not be too many of them. Let us go to the second part of our demonstration, here where we will see some equipment, which is used for testing of the construction materials; that is used in concrete beginning with coarse aggregate; these are the sieves in the lots of them, and they are just two of them, which are used to determine the particle size distribution of aggregates. We put aggregate samples whether its fine or its coarse, let them pass through this determine, how many or what fraction of the volume or the mass is retained on the different sieve sets and we get the particle size distribution.

Apart from the particle size distribution, these gauges are used to determine the flakiness and the elongation index for flaky particles and for elongated particles. So there is a process by which the aggregate sample is drawn and from that, we kind of identify certain amount of the samples, which need to be tested and determine the flakiness index and the elongation index using these gauges.

This here is a pycnometer, which is used to determine this specific gravity of the coarse aggregate and the fine aggregate. Coming to testing of cement, this is the flask which is used to determine this specific gravity of cements and in specific gravity of cements, we since we cannot use water, we use kerosene as a medium and determine the volume of cement and so on.

(Refer Slide Time: 24:05)

When it comes to testing, the strength of cement, we use mortar samples; this apparatus is used to determine the soundness of cement, what we do is to put a cement paste sample in this cover it and put this entire assembly in water have it, at the certain temperature and expose it for a certain period of time, and the measurement taken is the distance between these two ends of the fork. So we measure these distance initially and at the end, after the exposure and find out that. If there is any amount of deleterious expansion in this paste, then this distance will tend to increase, that is how we measure the soundness of cement.

(Refer Slide Time: 25:05)

This, here is the blends apparatus to determine the fineness of cements. Fineness of cement is expressed in terms of centimeter square per gram or meter square per kilogram and this determined using the blends apparatus, where we take a cement sample in this tube in a certain manner, close this put this on this surface here and then the cement sample, which is packed in this part as a wet. We allow a certain amount of air, using this contraption here to pass through that bed. And if the cement is very fine, then the amount of time it takes for a certain amount of air to pass through is much larger.

So, we calibrate this apparatus using a powder of known fineness. And we know, how much time it takes with respect to that time? How much time does it take for a given cement sample for the air to pass through and so on? We try to estimate, the fineness of cement in terms of the centimeters square per gram. That is the surface area per mass or unit surface area or specific surface area of the cement. Usually the specific area of cements is about 3500 to 3800 centimeter square per gram.

(Refer Slide Time: 26:21)

One of the important parameters for cement is, consistency standard, consistency setting time, initial setting time, and the final setting time. Now, all these tests are in principle based on penetration resistance; that is a paste, which is here in this mold. If the penetration resistance to this for a given load is high, then the material as set, if it offer. If it does not offer any penetration resistance, then the material is still very close to being a fluid, what we use is a vicat apparatus, which is shown here. And what we do is to place the cement sample something like this, and use these different plungers it could be a plunger; it could be a needle like this or it could be a very special type needle, which is like this. These are used for consistency initial setting time and final setting time.

What happens especially, the final setting time is a very interesting experiment, where we wait for the cement paste to set to the extent. That if you notice carefully here, there is a needle, which is penetrating just outside the round surface here. What we need to ensure, for the final setting time is that, the needle at the center should make a mark and the outside surface should not be visible. So once we fix these plungers, either it is this one here or it is this one ort, it is this one; we try to use this mechanism by which the plunger or the needle is allowed to fall into the cement paste and depending on the kind of penetration resistance, that we get we have our observations in terms of the consistency, standard consistency initial in the final setting time of cement, determined using a paste sample, which is here, which is placed in this mold and is nothing but, a mixer of water and cement.

This test can obviously, be now modified or adopted to determine the consistency or initial setting time or final setting time of another cement, which has placed where the cement has been replaced by a pozzolanic Portland cement or any other chemical admixture or a mineral admixture has been padded to modify the cement paste.

So, the principle of penetration resistance remain the same. The same apparatus can be still be used, except that the standards that we use the specifications, that we use the test method and so on. They will change depending on what kind of paste is being used. Strength of cement is determined using mortar. And this is a mortar sample, that we use and what we do is to fill this mortar in a mold of a certain size, which is something like this and what we get at the end of it, after it has hardened and so on. Is the cube, which is something like this and these cubes are tested for strength and we get a value of the strength of sand, we get a value for the strength of the cement.

Now, why do we use mortar and not cement paste? when we are determining the strength of cement, the answer lies in this specimen. Here you will notice that, this is a pure paste; that is just water and cement allowed to stand for a long period of time and we find that there are lots of these cracks, which are formed on the surface, these are shrinkage cracks, because of the heat of hydration and because of the dimensional changes in the cement, as it hydrates. Because this problem with cement paste, we do not use cement paste and rather use mortar. However, we have to be careful that the properties of the sand, do not affect the strength of the cement, which has been determined and therefore, what we do is, use standard sand.

(Refer Slide Time: 30:53)

This here is a set of 3 sands, which are used in the determination of strength of cement; this sand here if you notice is the coarsest and this here is the finest, and this as an intermediate sand. We mix apart of all these sands, in fact the indian standards requires the 200 grams of cement; we mix with 200 grams of each of these sands, so we have 800 grams of the powder or sand, and cement together mixed with a certain amount of water, to give the cubes; and we use those cubes to determine the strength of cement.

We have been talking about the difference between, this specific gravity of coarse aggregate or fine aggregate and the bulk density. The specific gravity is the density of the material parse. The bulk density includes the volume of voids, which may be there in the aggregate when it is packed.

Now, in order to determine the bulk density, which has its own use. We use a fixed volume container something like this, fill it with aggregates in a certain manner, whether it is 3 layers or 4 layers or whatever compacted, using a temping rod, which is something like this. Once the compacted aggregate is filled in the in a container something like this, we know the volume of the container and we know the mass of the aggregate from that given this specific gravity.

We can find out, how much is the void ratio? what is the extent of the void is present? For example: This is a container, which we use for sand; it has been filled with sand and obviously, what it means is that the sand has been filled in the container but, within the sand particles, there are still a lot of voids.

How much voids are there, can be determined by pouring water into this, and finding out what was the extent of voids and similar exercise is carried out, using a larger container for the coarse aggregates. So, this is the container, which has been filled with sand and if we know the mass of the sand, which has gone into this and the volume of the container, which is very easy to determine. We can find out, the bulk density we can use this specific gravity determined using a pycnometer, to find out how much is the voids in this container?

The similar exercise is carried out for a larger container, for the course of for the case of coarse aggregate. Now this is a hardened concrete core, now if you look at it closely, we will find that there are aggregate particles of different sizes, which are embedded in a matrix of mortar. This is what we have been talking about all along in the lectures.

Now, let us try to see how this principle actually operates? If we have a certain amount of water taken here, then if we had any material to it, the volume of water or the level of water keeps increasing, because part of the water is getting displaced by the aggregate and this is not only and this is true not only for coarse aggregates but, also perhaps for sand.

So, if we have added stand to the system, the level of water have increased, so basically the what we talked about in the class was that, if we want to fix the volume of this container, which will get to be a 1000 letters or a cubic meter and the proportioning exercise really boils down to, how much water should be there? How much aggregate the coarse aggregate and the fine aggregate should be there? And how much cement should be there in order that their total absolute volumes become a cubic meter or a 1000 liters?

This principle will now be demonstrated, to you through mixing cement with water to make paste, add fine aggregate to it, to get mortar. And then add coarse aggregate to it to get concrete to make the discussion quantitative. Let us take 1/2 a kg of water, which is 500 ml of water and we will mix this with a kg of cement.

Now, what that means is that, the water cement ratio of that paste will be 50 percent, there is 500 grams of water and a 1000 grams of cement mixed, we will get a water cement ratio 50 percent paste; this here is the cement paste, that we have having water cement ratio of 50 percent.

I would like to draw your attention to seeing, how fluid is the fixed contrast? This paste which has a water cement ratio of 50 percent with a paste like this, which has a water cement ratio of about 30 percent, now in this paste we have less water far less water than this paste here. So what this shows, is the basic principle that if we keep increasing the water content in the paste, the fluidity of that paste will keep increasing its, an obvious conclusion but, has major implications. As we shall see in this paste, which has a water cement ratio of 50 percent, we will now add about 1.3 kgs of sand, and what we will get is mortar? So this is the cement paste having a water cement ratio of about 30 percent.

Now, you can notice that this it has no flowable consistency, it is a fairly hard. Now if we want to add or if we add some chemical admixture to it, which could be a water reducer, what happens is by adding a chemical admixture in a suitable dosage, we can get the same paste having a water cement ratio of 30 percent to have a virtually flowable consistency like this, this property of chemical admixtures, which is a water reducer could be used to reduce, the amount of water, that is required for a given consistency.

What we have seen in this experiment, is the chemical admixture being used to increase the consistency or the make paste flowable. If we turn the observations, the other way round. We can use this chemical admixture to actually reduce, the amount of water required for a given consistency; and now consistency of this paste is the critical factor, when it comes to the final consistency of the concrete. As we shall see when the consistency of that paste changes, as sand is added to the system; that is its becomes mortar and then coarse aggregate is added to that system and it becomes concrete.

Now, let us add coarse aggregate to this system and what we will get is concrete, we are adding coarse aggregates of two radiations; the smaller version which is about 10 mm aggregate and a larger version, which is 20 mm aggregate, both these size factions are about 1.3 kgs again.

So, let us add the coarse aggregate to the mortar and see what happens to the concrete, this is the concrete that has been produced by mixing 1.3 kgs of 10 mm aggregate and 1.3 kgs of 20 mm aggregate to the mortar, which add 1.3 kgs of sand added to a fixed. So, now this volume of concrete here has been produced, using 500 grams of water, 1000 grams of cement, 1.3 kgs or 30 100 grams of fine aggregate and 20 600 grams of coarse aggregate. So, this is the concrete, which we now have and finally, if it was allowed harden, what we will get is a core, which is something like this. So, we must understand that the properties of the harden concrete are related to the properties of fresh concrete and the properties of the fresh concrete parse in terms of workability, and so on are related to the properties of paste and the amount of water, that has gone into the system.

We must remember that, workability is related to the amount of water and the strength is related to the water cement ratio. Now here is the concrete, which is stiffer than the previous concrete; it has a smaller amount of the water content and we will get a much lower slump value, than we oared for the previous concrete.

Now, as I showed with the case of simply the paste, if had a chemical admixture to the same concrete, which is here, which is reasonably stiff by adding a chemical admixture. This concrete has been fluidized, it does not behave as a perfect fluid but, it is a higher slump concrete than this one. So, we have show we are trying to show, how chemical admixtures can be used to plasticize a concrete again. We can use the chemical admixture to reduce the water demand as, we showed in the case of cement paste, when we look at the concrete having a super plasticizers as this as in this case, we should be careful to notice that the concrete does not segregate, that is it should not happen that the coarse aggregates, become separated from the mortar phase. So, in this particular case, we are seen signs of segregation in the concrete mix, because the chemical admixture was added without a consideration to segregation.