**Concrete Technology**
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**Lecture - 4**
**Cement: Properties and Tests**

Welcome to module 1 lecture 4 of Concrete Technology, we shall be discussing today cement properties and test.

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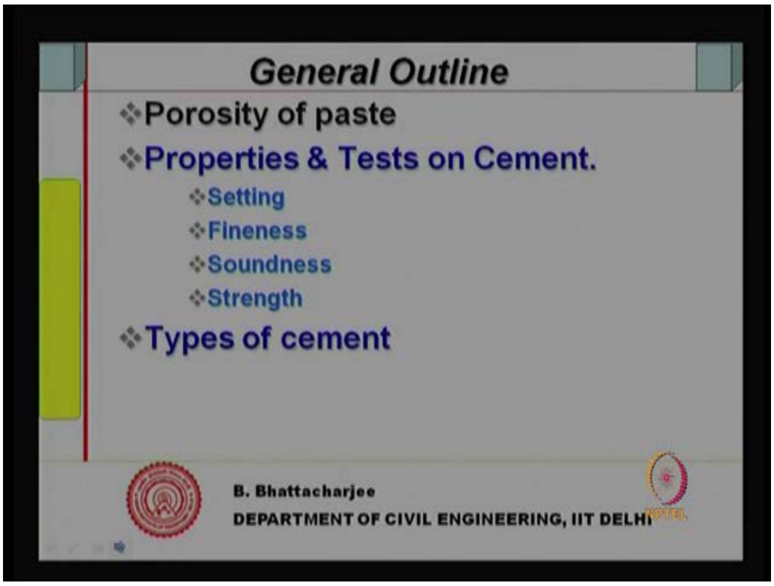


But before that we shall be actually starting from where we have finished in the last class. So, we will talk of porosity of paste then we will look into properties and tests on cement, setting, fineness, soundness, strength and lastly we will look into types of cement. I will just start these types of cement, so let us start from where we have stopped in the last class. We are trying to estimate the porosity in you know of cement paste. In our earlier lecture we recognized two types of inherent pores in the cement paste; one we called it as gel pores, which is a part of the structure of the product of hydration and second one is capillary force.

Also we stated since the reaction takes relatively long time and is not instantaneous, but the structure, solid structure forms quickly. Therefore, as the hydration progresses, hydration product occupies the space that was originally filled by water. And that is how capillary porosity reduces, because capillary porosity are those pores which are left blank, which were actually originally water filled space and are left blank, because hydration product could not fill those originally water filled spores.

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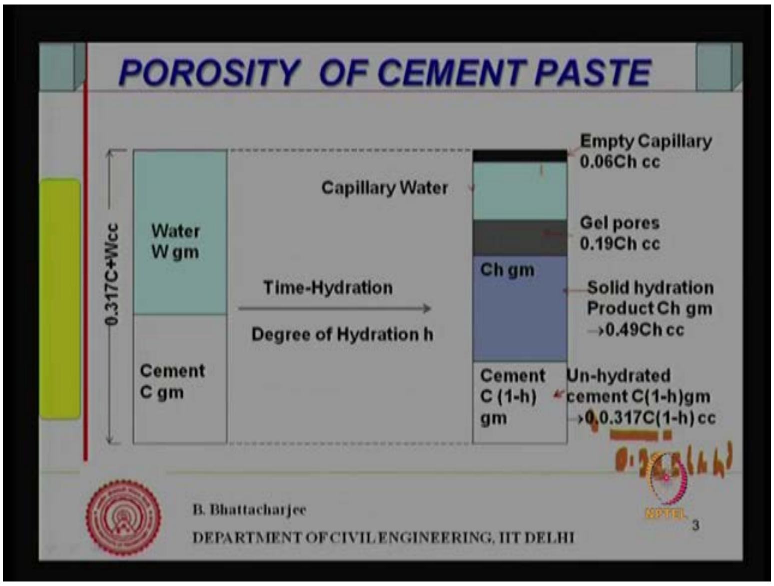


So, let us see, let us start from this figure, porosity of cement. If you recall the last class, we said let C gram of cement, we add W gram of water to it and with time Hydration progresses. Let's say our degree of Hydration is h, then Un-hydrated cement will be C into 1 minus h, because h is the fraction of cement Hydrated. The fraction remain Un-hydrated will be C minus, C into 1 minus h by mass and corresponding volume is given by this 1, you know specific gravity of cement being known it is 0.32 C, we can say 0.32217 C into 1 minus h.

This is the Un-hydrated cement; C h is the mass of the cement that has reacted, because h is the degree of hydration, means fraction of cement that is reacted. The volume of hydration product we know it is C h grams 4.49 C h c c, 0.499 C h c c. So, volume of product hydration product C h gram is 0.49 C h c c and then corresponding gel pores is 0.19 C h c c, so you have derived all this in the last class. This is the space remain unoccupied and would be capillary remain, will remain as capillary water and this portion is empty capillaries and we have also calculated this as 0.6 C h c c.

Now, total initial volume of cement plus water is 0.317 C plus W c c or 0.32 C, approximately this can be written as 0.32 C plus W c c, so this is the total volume. This volume is conserved, because this will as it hydrates, this will solidify quickly and the skeleton structure will comprise of this total volume. So, hydration product must occupy this volume including the words spaces, complete hydration product including word spaces must occupy this volume, so this 2 volumes are conserved.

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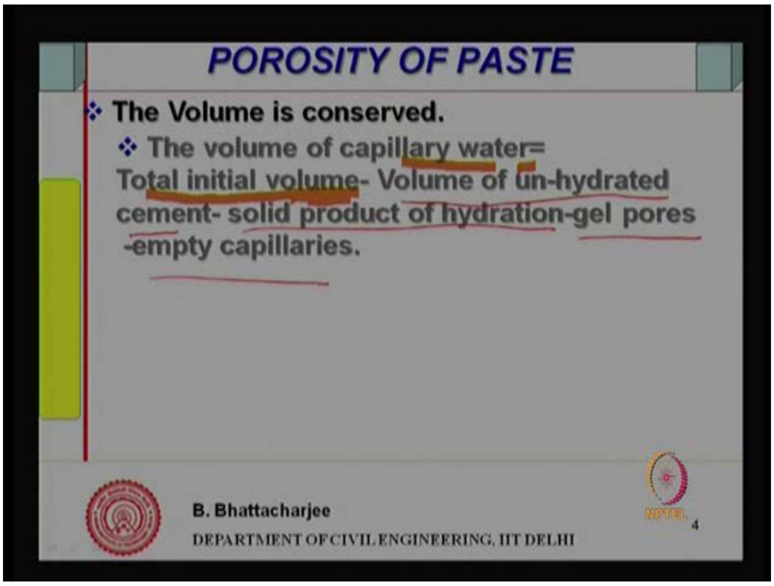


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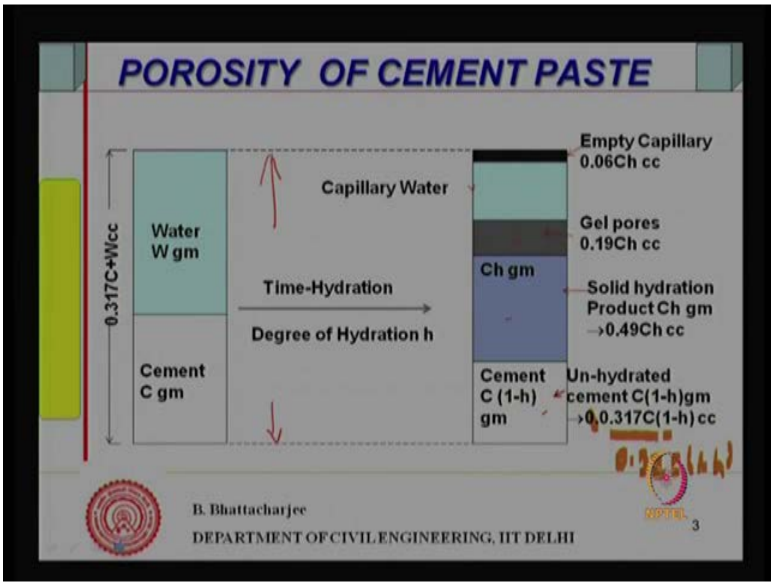


On these bases, it shall be able to calculate out the volume of capillaries. So, volume of capillaries we calculate out as, because the total volume is conserved, the volume of capillary water is calculated as total initial volume, total initial volume, total initial volume, minus volume of Un-hydrated cement, solid product of hydration minus gel pores and empty capillary, so what we are doing?

We are actually subtracting from this total volume, from this total volume, we are subtracting this, this, this and this, so we will get this volume.

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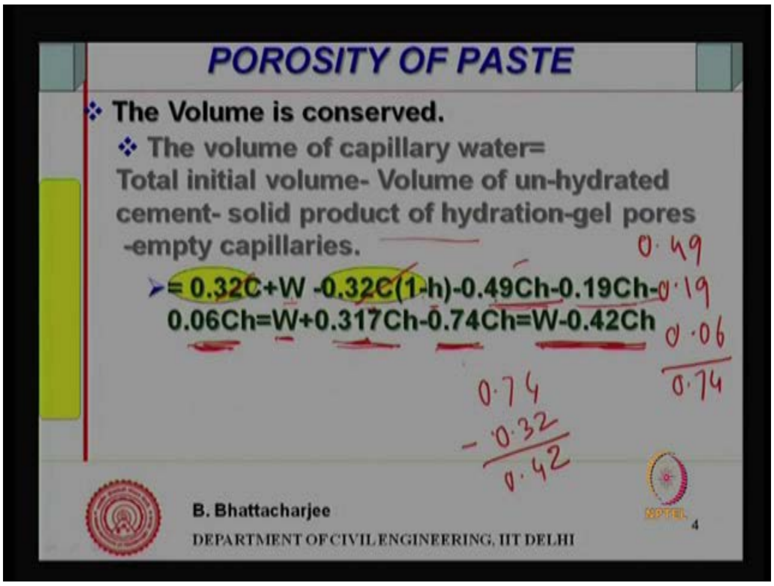


So, from this total volume we are doing this and that is how we can get the volume of empty capillary or capillary water, volume of capillary water, we can find out total initial volume minus volume of Un-hydrated cement, solid product minus solid product of hydration minus volume of gel pores and empty capillary. So, if you do that, this was to known to us was total initial volume was 0.32 C plus W, volume of un-hydrated cement is 0.32 C 1 minus h from the previous diagram.

This is the volume of hydration product 0.49 in C h solid product of hydration, gel pore is 0.19 C h and this is empty capillaries and in this one you can see that 0.32 C and 0.32 C into 1, this will cancel out, because there is a minus sign. So, you will be left with the rest of the thing, so this W will come here, 0.32C h plus this will be there, because there is a minus here, there is a minus sign here. So, this is remaining here as 0.32 you know rounded off to 0.32 and 0.49 and 0.19 sum up gives us 0.74 C h, 6 h C h plus 0.06 C h all this sums up as 0.74 C h, because 0.49 plus 0.19 plus 0.06 will give the 0.74, so this is 0.74 Ch and 0.74 minus 13274 minus 0.32 is simply 2042.

So, I get volume of empty capillaries as W minus 0.42 C h, because this will cancel out together with this, so left is W and this minus in this minus makes it this and rest of the term if I sum up I get 0.74, so total I will get something like W minus 0.42 C h.

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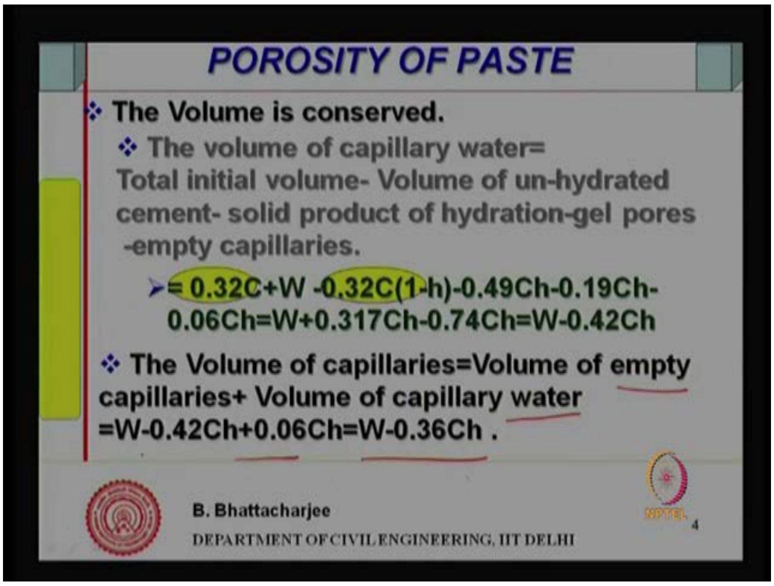


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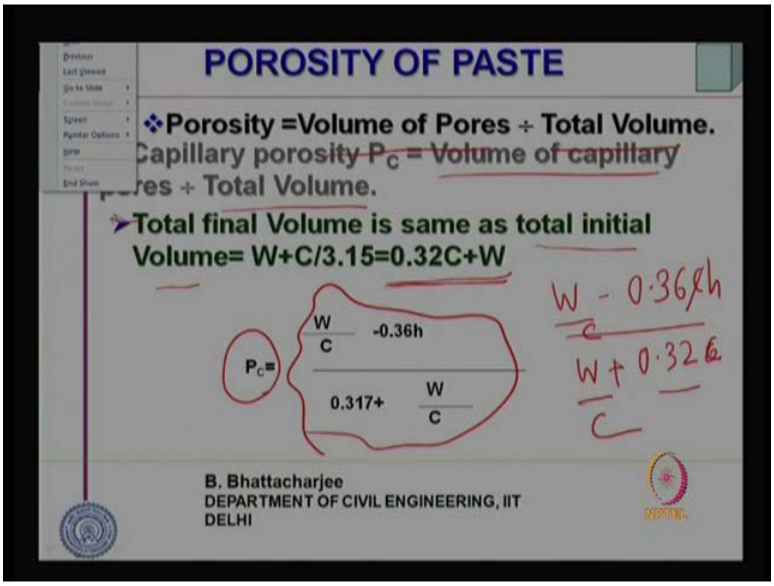


Thus the volume of empty capillaries, total volume of capillaries will be volume of empty capillaries plus volume of capillary water and this if I sum up W minus 0.2 C h plus 0.68 I guess I get W minus 0.36 C h. So, total volume of capillaries in the system will be W minus 0.36 C h. Thus I can get in expression for capillary porosity I can get in expression for capillary porosity; I can expression for capillary porosity. Capillary porosity will be volume of capillary force divided by total volume and what is total volume? It is the sum of originally added cement volume plus water, let us see.

So, porosity is volume of force divided by total volume, volume of force divided by total volume, capillary porosity is the volume of capillary pores divided by total volume and the final volume is same as the total initial volume. Therefore, this is nothing but 0.32 C plus W that is what we have seen and therefore capillary porosity will be W minus 0.36 C h divided W plus 0.32 C and if I divide both side by C, so this will cancel out I will have W by C W by C 0.32. So, you can see that capillary porosity is given by this formula capillary porosity is given by this formula, all right?

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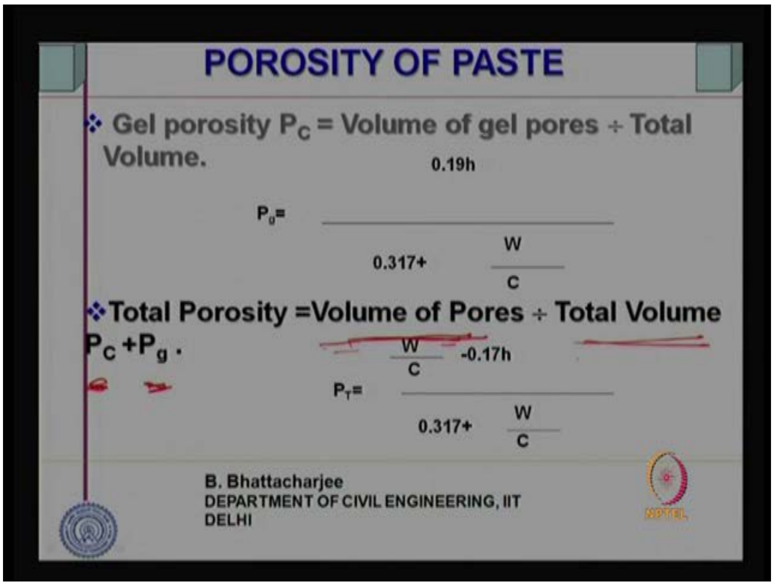


Similarly, I can find out the gel porosity, similarly I can find out the gel porosity, so gel porosity will be what? Gel porosity would be, volume of gel force divided by total volume, volume of gel pores divided by total volume and we call volume of gel pores 0.19 h into C and this was W plus you know this C, so C if I divide both side by C I get 0.19 h, 0.19 h divided by 0.317 or 0.32 plus W by C, so this is the gel porosity.

So, if I sum this subtotal, now I will get the total porosity, so total porosity is volume of gel pores you know total porosity volume of gel pores bar plus capillary force gel force volume of force total porosity I divided volume of force divided by total volume. Total volume of force divided by total volume and this is nothing but sum of gel porosity plus capillary porosity some of gel porosity plus capillary porosity and which will be you know which will be if I sum it up, so what do I get?

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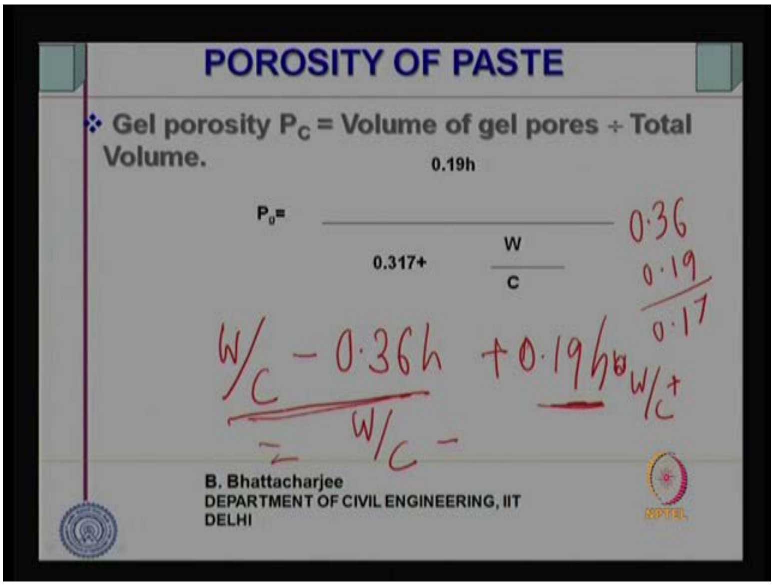


Just let me do the summing, let me do the summing, W by C plus you know just do it like this, let me do it here W by C minus 0.36 h plus 0.19 h is equals to W by C minus 0.36 divided by 0.19 is 0.17. So, if I sum up volume of you know capillary pores plus volume of gel pores divided by C off course, than just let me do it again.

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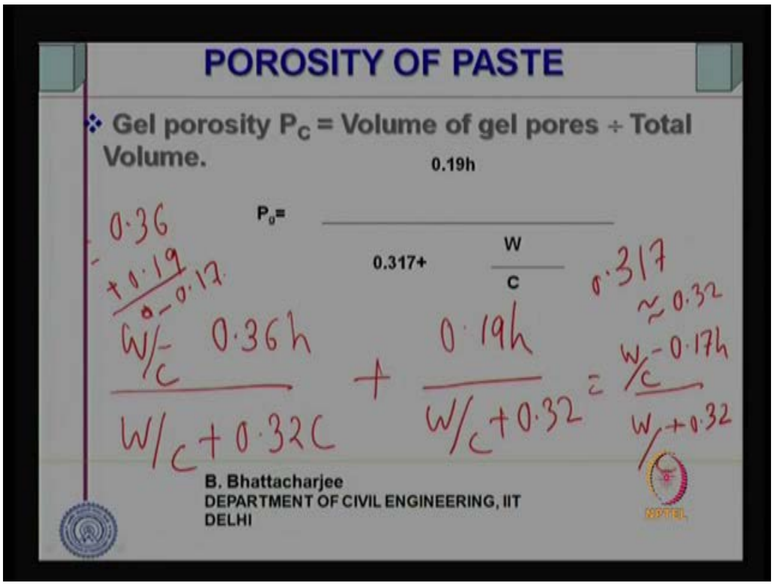

Capillary, volume of capillary porosity was W minus 0.36 h divided by W by C plus 0.32 C plus 0.19 h divided by W by C plus 0.32 C, you know 3.317 is approximately equals to 0.32 that is what I am using. So, if you sum this up you will get W minus 0.17 h divided by W by C, W by C plus 0.32. So, this is what you will get, because minus 0.36 plus 0.19 is equals to minus 0.17, so this follows therefore.

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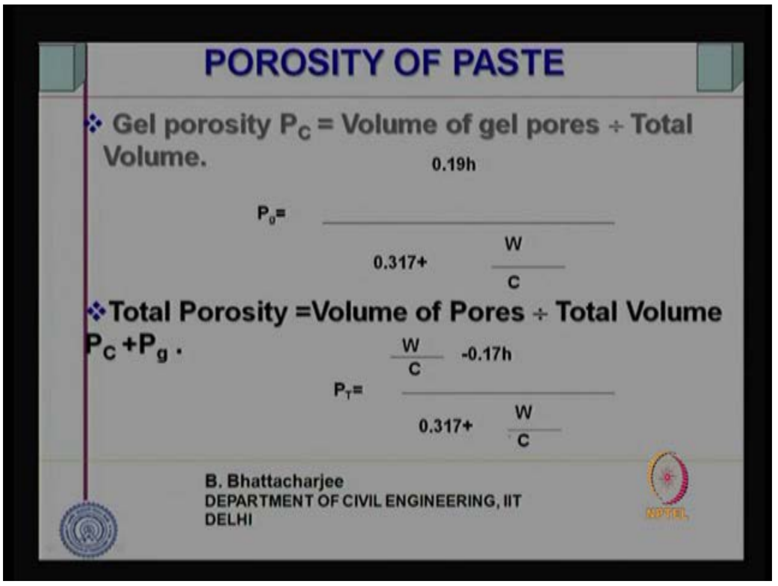


Summing up these two would give me total porosity as W by C minus 0.17 h divided by this. So, this is how I can determine the total porosity of cement paste.

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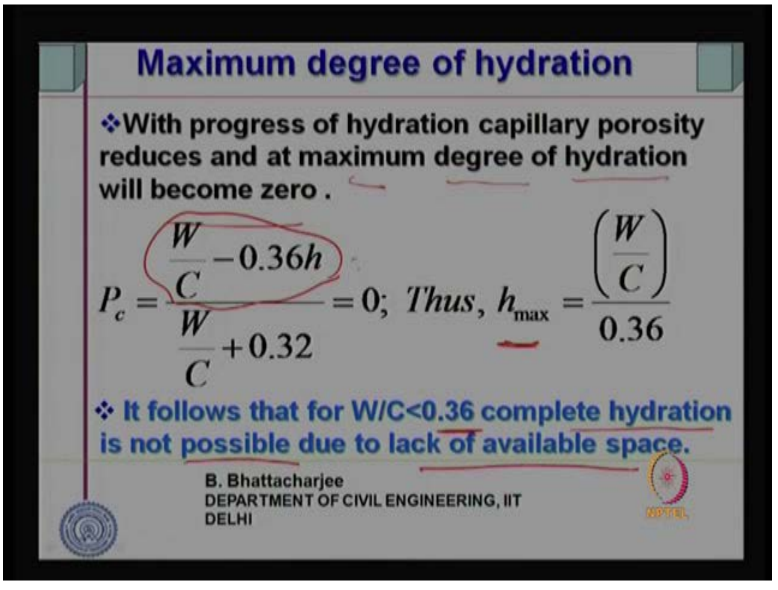

Now, you see the total porosity of cement paste is important, but one interesting thing is that you know for complete hydration, for complete hydration the water cement ratio, minimum water cement ration required for complete hydration I can derive from this concepts. Now, if I have less water, then the originally water filed space will be small and if it is small the hydration product won't be able to occupy this space, because the space is not available. Because if the original water filled space is small or proportional of water or water cement ratio is small, volume occupied by water would be small and thus hydration product will not have sufficient space to fill in, you know sufficient space for itself to occupy.

Now, it does not have very, this product do not create any pressure, all though cement with water after reaction expands, but it does not create pressure of this volume expansion due to hydration is not so high. As to either disrupt the solid structure of the cement paste or create new space. So, maximum degree of hydration is limited by the originally, you know quantity of originally added water or in other words by water cement ratio, let us see this. So, progress of hydration capillary porosity reduces and maximum degree of hydration will become zero if I do not have sufficient space. So, therefore you can see that capillary porosity is this and for this to be zero, maximum degree of hydration is W by C by 0.36.

In other words, if I have a water cement ratio less than 0.36, I will never have complete hydration. In other words, if I have water cement ratio less than 0.36, this term will be negative, you cannot have negative capillary porosity that means you need more space than that is available. Therefore, water cement ratio for water cement ratio less than0.36 complete hydration is not possible due to lack of available space to be filled by product of hydration. This is because Hydration is not instantaneous reaction, this reaction takes some time, and solid skeleton is formed within a short period of time.

The solid skeleton will have capillary space within it, occupied by capillary water, as the hydration progresses, which progresses which progress is a very very long period of time compared to the initial setting time, let us say, or solidification time. This product of hydration would occupy the originally water filled space. Now, if you have less water in the beginning, you will have less space, so product of hydration where did it go? It does not have space, so simply it will not be produced. That is how maximum hydration possible is limited for low water cement ratio, cement paste or concrete for that matter. So, if the water cement ratio less than 0.36, complete hydration is not possible, right?

So, at 0.36 degree of hydration is maximum possibility degree of hydration. But more than that there are some other factors which we have seen in the last class, that water cement ratio in by with water, with water cement hydrate, degree of hydration is also a function of water cement ratio. Therefore, degree of hydration is a function of water cement ratio and therefore, question of 100 percent hydration with ages just it is not there, it is simply it won't be there, because the degree of hydration is assumed to t, to some value of function of water cement ratio. So, in any case below 0.36 it can never fully hydrate.

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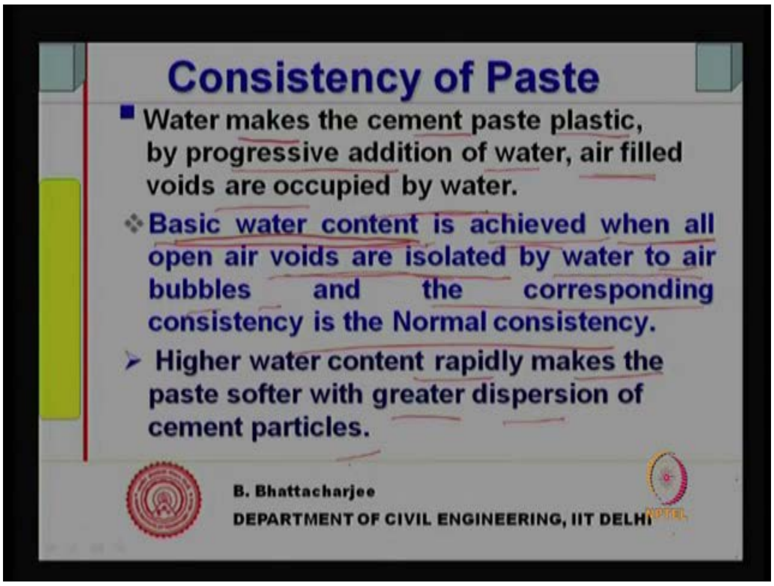


Now you can look into consistency of paste, so far we looked into the porosity which we actually continued from the previous class. Now, you can look into the consistency of paste, some properties, so it is one important properties consistency of paste related to amount of water that is required to be added to make it uniform paste, because when you add water, when water is added, water makes this cement paste plastic, you add little bit of water it makes it plastic and by progressive addition of water, air filled voids are occupied by water.

So, in the original system cement particles will have air filled space in between them, this particulate system where level of given kind of packing, but within the grains or within the particles of cement, the void space will be filled by air. As I add water, this water filled space will be filled by, air filled space will be occupied by water. Now, basic water content is achieved, so you go on adding the water, water content we call it basic water content. It is achieved when all open air voids are isolated by water to air bubbles, so what happens we just see by diagram that.

As you go on adding water, air paths were all interconnected, the interstitial space between the particles were all connected by air. Now, you add water this space will be filled in by water, now when as each you know, as when a situation will arise at certain point of time, as you go on adding water a situation is arrived at certain point of time. When air filled spaces will become disconnected, earlier they were all connected, but they will become isolated that condition the amount of water that is required to arrive that condition we call it as basic water content, we call it as basic water content. It is achieved when all open air voids are isolated by water to air bubbles and the corresponding consistency actually is normal consistency.

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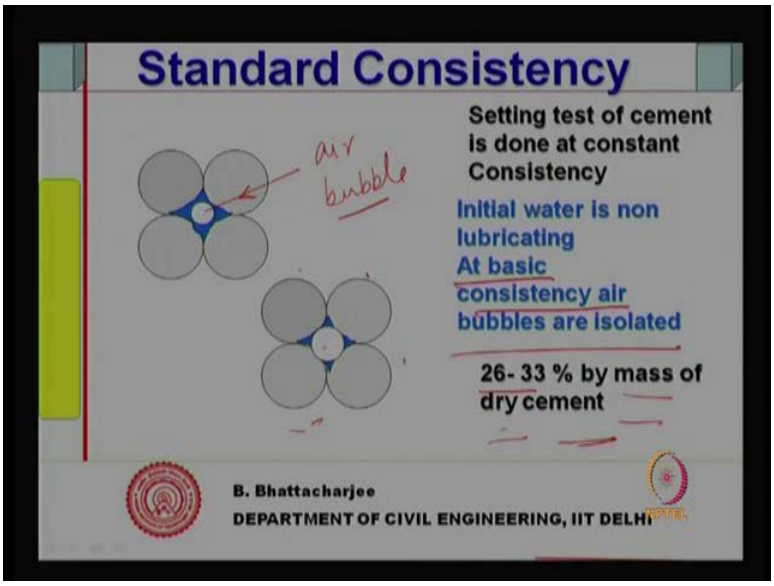


So, corresponding consistency is normal consistency, if you add more water it makes the paste softer and greater dispersion of cement particle may occur. So, cement particle can also get separated if you off course use a dispersing agent, otherwise you know the possibility of getting separated exist they might be clog, but each clog system will be separated out by water. So, if you add more water paste and mix it properly, the cement particles may be separated by water from each other.

Let us see diagrammatically what it is so setting test, setting off course, important issue is setting test of cement is done at constant consistency, so this is important. Initial water is non-lubricating at basic consistency air bubbles are isolated, this is what we are looking. So, that is what we are saying consistency is important, consistency partial may not be as important, but then we do setting tested a constant consistency. Now, how can you define consist a constant consistency, because it was than initially empirically trough a particular test which will talk about. But then, this you know this water content corresponding to the standard consistency will not, you can be defend really and therefore that is at, that consistency we do the test.

Now, that consistency correspond to basic water content as I mention and consider this is cement particle and other cement particle and another one and another one, they have a simple cubic packing. For simplicity we assuming there simple cubic packing, this has got simple cubic packing, for simplicity we assume that this has got simple cubic packing and the space here is air void, space here is air void. So, as I add water, some of this void space are filled by water, a pendular state, nearly pendular state, not really pendular state, so you have water filled here and air void inside and air is still touching to the cement system, air is still touching to the cement system and the air voids may still remain interconnected.

But if you like more water let us say, give at more water, a time will come when the air bubble get isolated, so this is my air bubble, this is the air bubble and as it get isolated this corresponds to basic consistency. So, there when just they are isolated that means, just when the pendular state it is reached, that is what corresponds to basic consistency. If you add more water rapidly it will become, it will become the paste will become, you know more plastic. Now, this standard consistency is, this corresponds about to 26 to 33 percent by mass of dry cement, this corresponds to about 26 to 33 percent by mass of dry cement, how do you measure this?

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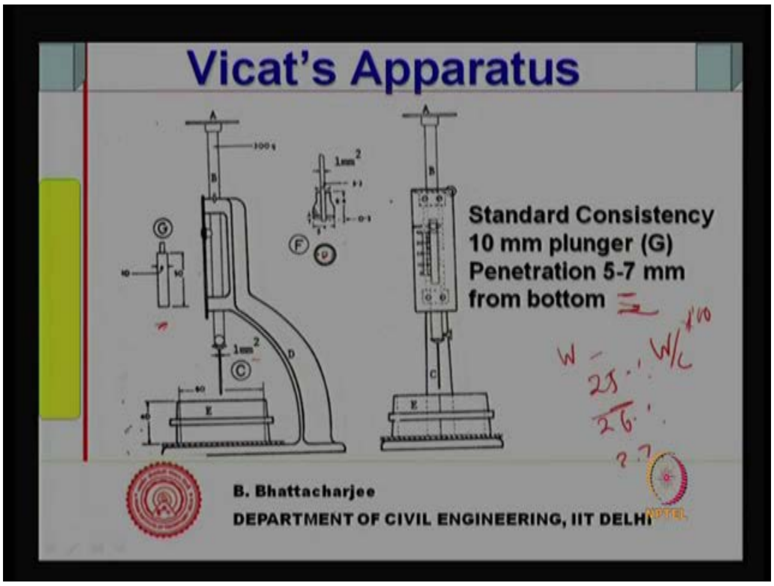


We measure this by an apparatus called Vicat's Apparatus, in fact this instrument came first, the concepts of the basic consistency came much later, there was given by power in fact in 1950s this was in a in 19th century. So, this test, this is an empirical test and empirical device developed in order to arrive at setting, time, consistency, etcetera, of cement. Now, this apparatus has got, you know this is your cement in a mould, paste in a mould the mould will dimensions are given, not very important for our class to look into the dimensions. So, dimensions are given and you have got a needle, which are called Vicat's needle. I mean more than one needle, you have been in fact you have got first 1 millimeter square needle and then this is needle plus a small plunger.

The small needle 1 millimeter square, then a plunger which larger diameter and with a small gap between the tip of the needle and the plunger bottom, the dimension are given. So, it can make an impression onto the paste like this, the centre point the needle will make an impression like this and outside the plunger boundary will make an impression like this and this is 1 meter square needle, this is a needle 10 mm square. So, these 3 needles are used to determine standard consistency, initial setting time and final setting time.

So, let us see what standard, how standard consistency is determine, this needle 1 can lift it up and place it just on top of the cement here, cement paste here and allow it to drop on his own. So, standard consistency is determine by this plunger, 10mm plunger, that is this one and its penetration should be, when the penetration reaches 5 to 7 millimeter from bottom, so find out the time, time at which penetrations of consistency, you know the time at which 5 to 7 millimeter from the bottom is reached. Now, that time you know first you go on adding water, so increase the water, increase the water, start with a water maybe 25 percent, go on increasing 26 percent 27 percent, etcetera, etcetera and find out the penetration, when the and penetration can be let us say total penetration can be 40 millimeter.

Now, you measure the penetration from the top, because there is needle as got a, you know you can measure the needle they will be graduation and if you measure from the needle how much it is penetrated, so how much it is from the bottom that you can find out? The water content or mass you know W by C expresses percentage, when at which the needle penetration between it becomes between 5 to 7 that corresponds to standard consistency. So, this is you can see that this is an empirical test, purely an empirical test devised by we (( )) in order to come to the standard consistency. In fact the basic water content which I talked about, this was a postulated by T C Power and there team in 1950s and it first they looked into this basic water content that which actually it becomes uniform, consistent and after that rapidly becomes plastic re-added additional water.

Now, they then they found the basic water content, they actually the term, you know the designated the water content, which they designated as basic water content, water content corresponding to basic consistency, that is same as standard consistency, that you roughly same as a standard consistency that you obtained from the Vicat’s test, so standard consistency is this.

Now, this test is off course, important from the point of view that we test setting time at this water content, because you have to keep certain things constant, you want to find out setting time, so you have you consistency we keep constant, because fineness the setting time may be dependent on fineness of the cement. But at the same time the fineness will also come on the consistency, so a paste we you know how much water you should be added, we do not keep the amount of water constant rather we keep the consistency constant and the water required to attain standard consistency, because some cases it may be very dry.

Supposing the cement has got a very high standard consistency, because lot of water in order to arrive at that basic water content, in that case if you would have kept the water content same at a low water content, low water content it should have been very very dry. So, the penetration of the needle would not have been possible, not because, not because the cement characteristic, but because of the consistency or plasticity of the paste itself. So, plasticity is maintained constant and then setting time is measured and this plasticity is related to the standard consistency that is why we got to get standard consistency.

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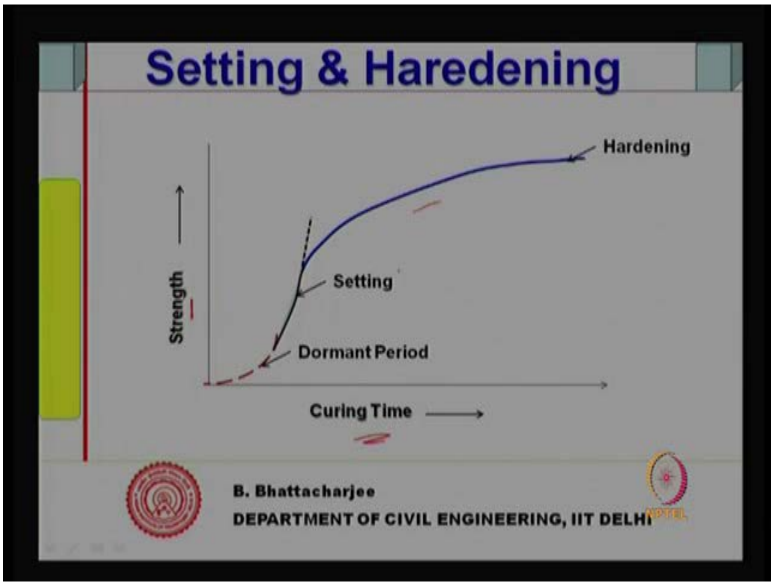


Let us see what we understand by setting again, we have discussed this a little bit earlier or few classes earlier, that its actually cement become solid with time as the hydration as the reaction progresses, as the reaction progresses it become solid with time. So, this solidification in a way is actually related to setting and hardening is (( )) gain of strength. But strength gain due to takes place during solidification also, because liquid if you apply force its simply deforms, so it is in plastic state. I mean liquid off course is deforms just on its own without any load, a plastic material is one where you put a constant load it will gone continuously deforming.

Liquid does not have a definite shape, so it just deform, just deform from its own weight or just deform straight away, you put it any pot it will take shape of that pot, a vessel, shape of a vessel. But a plastic material you put any load it will simply deform, all right?

So, solid is one which has got a definite shape, if you want to cause its deformation you have to apply load and that is its deformation is governed by hook's law. So, stress strain relationship as we understood, therefore during solidification some strength gain does take place, because after all from plastic to it is going a solid state, so let us see schematically we can represent. Initially it will be Dorment Period where there is no strength gain, y axis is strength x axis is curing time let us say, so no strength gain.

Then there will be rapid strength gain and this process is setting, so it will solidify, it has solidified actually quick strength gain is occurred. But during the hardening process this is the process of hardening, the strength gain will follow in this manner. So, this is what we have understand hardening essentially is related to strength gain, setting is related to solidification, but strength gain do occur in that period days.

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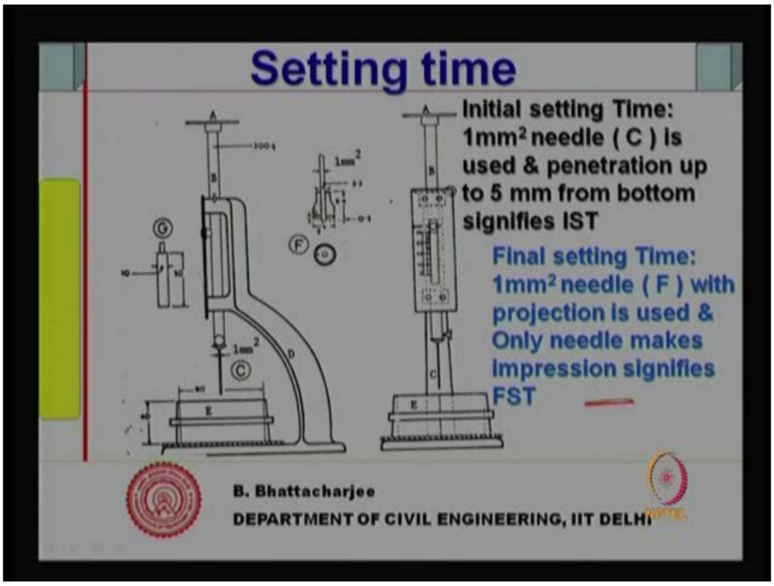


Setting is measured again by this Vicat's apparatus, but now you have a different needle, use this needle. Initial setting time is for with 1 millimeter square needle and penetration up to 5 millimeter from bottom signifies initial setting time. So, the needle has change standard consistency this needle, initial setting time this needle and final setting time we use this where this needle 1 millimeter square needle, this is 1 millimeter square needle with its projection is used such that you know when only this needle makes this is projection there is a small point 3 millimeter projection.

So, when this projection makes a mark on to the cement paste stop, but this mark the outer peripheral mark is not there. Then only the needle makes an impression other one does not make any impression, that is penetration is very very small, it is less than point equals to point 3 millimeter the other one is not penetrating, this one is not penetrating, this end this not penetrating, this end not penetrating, this end not penetrating, that is called final setting time. So, when this, this is penetrating, this tip is penetrating, this end does not leave any mark, that we call as final setting time, that will we call as final setting time. So, this is how we measure the setting time and this is the concept of setting time of cement, setting time of cement.

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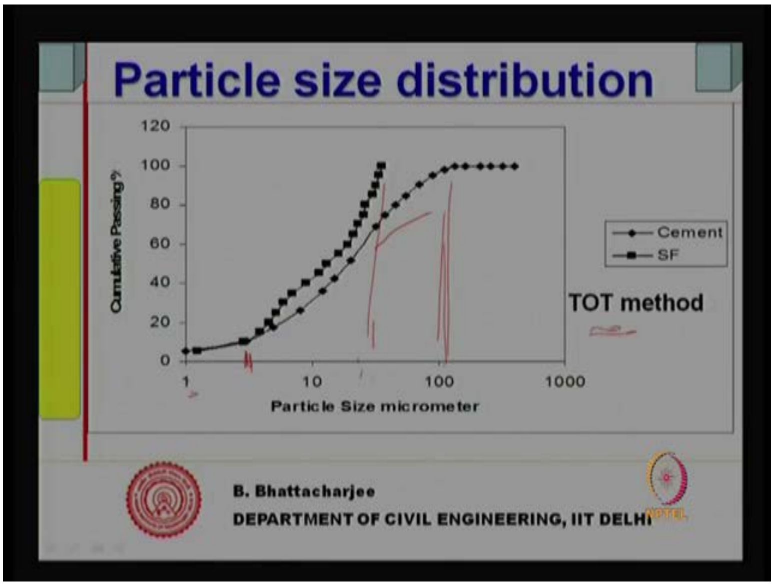


Particle sized distribution of cement is important, particle sized distribution of cement is important, in other words fineness of the cement is important. Finer the cement it will react fast, but at the same time it will require more water for wetting or standard consistency. So, fineness is particle sized distribution of cement is very very important, finer cement can gain strength early, can gain strength early. Now, how do you measure particle sized distribution of sizes, particle size and its distribution of cement? There can be several techniques, highly instrumental technique like this is this time of transition method as it is called, this is called time of transition method, that gives us particle size this is for let us say cement.

So, varying from 1 micron to somewhere around 100 microns this what some cement, ordinary Portland cement and another material Celica fume which will discuss later shows particle size much smaller, maximum is somewhere there (( )) could be somewhere there, so one particular Celica of fume better one may have max all particles somewhere there. So, you can see the cement particle size that is depend, you know? This particle size and its distribution, that is what is the range of particle size is, mostly it is from about you know this is this should about 5 micron, so 5 micron to less than 100 micron is the size of this particular cement by this method.

But supposing you use another method called laser diffraction, you might get somewhat different. This is time of transition is also a laser based method, there are several advanced method to through which you can determine the particle size distribution of cement.

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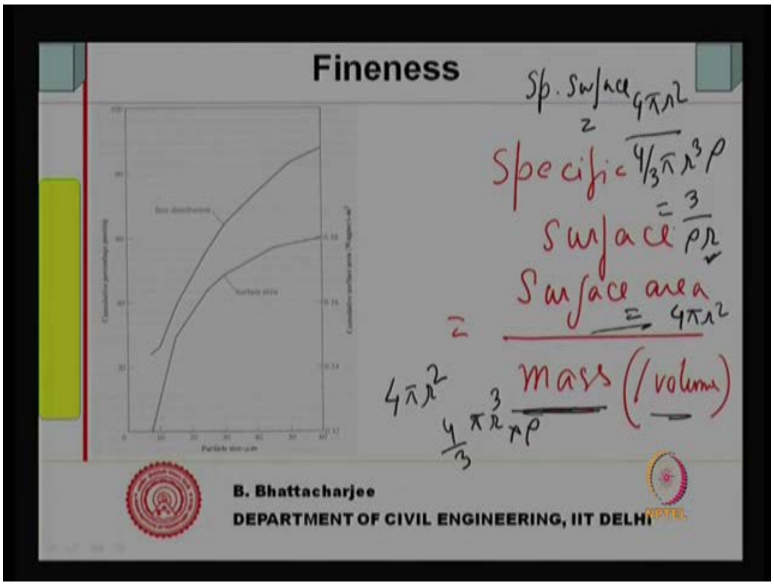


But there are simpler methods which are also used, for example we use specific surface, concept of specific surface, you know specific surface is defined as the surface area per unit mass or may be volume, which will look later on, so specific surface per unit mass or volume. Now, in case of cement, off course you use surface area per unit mass. Now, you can see this, supposing I have got spherical particle, for spherical particle surface area for a single particle is 4 phi r square 4 pi r square, volume is phi r cube 4 by 3 phi r cube into roe the density. So, specific surface would be equals to 4 phi r square divided by 4 by 3 pi r cube into roe will be equals to 3 by roe r. So, finer the particle more will be the specific surface, finer the particle.

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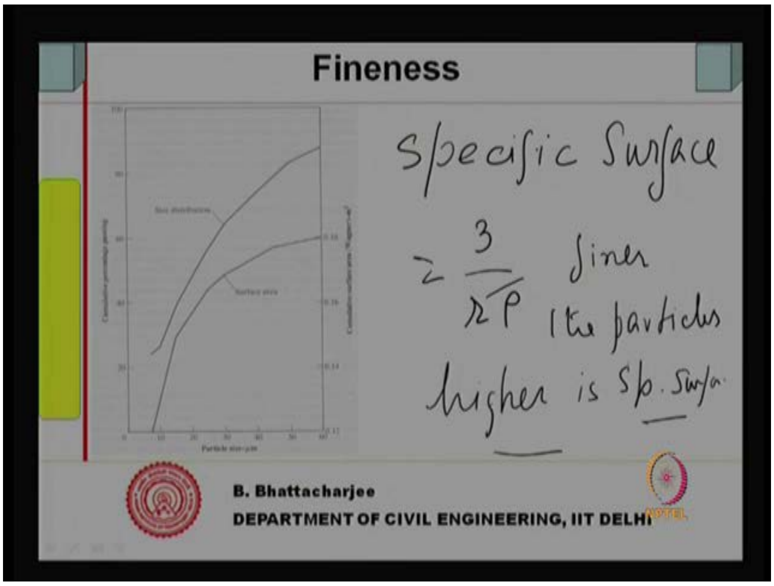


So, let me just write this again simply, specific surface is 3 by r roe, finer the particles higher is specific surface. Therefore, specific surface, higher specific surface means finer particle, higher specific surface means specific particle.

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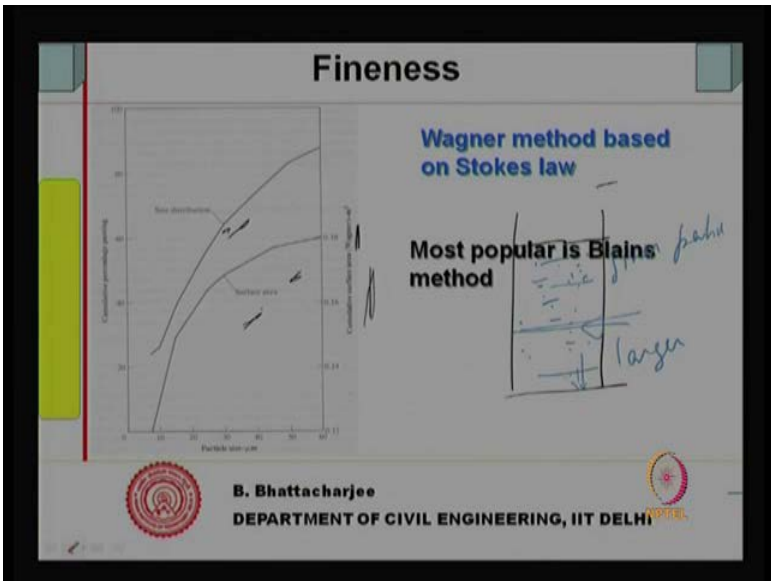


So, we determine in case of cement we in case of cement, surface areas, specific surface you see the cumulative percentage passing fraction, this is ship size maybe in microns, this could be in microns and this is specific surface by a particular method is call Wagner Method. So, if you look at the size distribution surface area has got a relationship with size distribution. If I can find out by particle size distribution, specific surface or surface area, I can find out you know correspondingly, higher the surface size distribution specific surface is in this manner.

So, it's related, this Wagner method is based on Stokes law, what is Stokes law? I will not go into the equation, but supposing I have got tar bit mixture supposing I have got a tar bit mixture I have got tar bit mixture I have got tar bit mixture, particles are there this one, finer particle, larger particle comes here, below larger one, first large particle larger, then finer particle.

So, you might have done as in soil hydrometer analysis, Wagner method is based on similar principle, but you can view, view this through optical method, number of particles at this depth, number of particles at this depth and other depths, etcetera etcetera and you can get the specific surface. You can also determine the size distribution and if you determine the size distribution that is how the relationship is. Now, most popular off course, is Blains surface area measurement, you see there are other measurement called Blains surface area measurement and most popular is Blains method for measurement of surface area.

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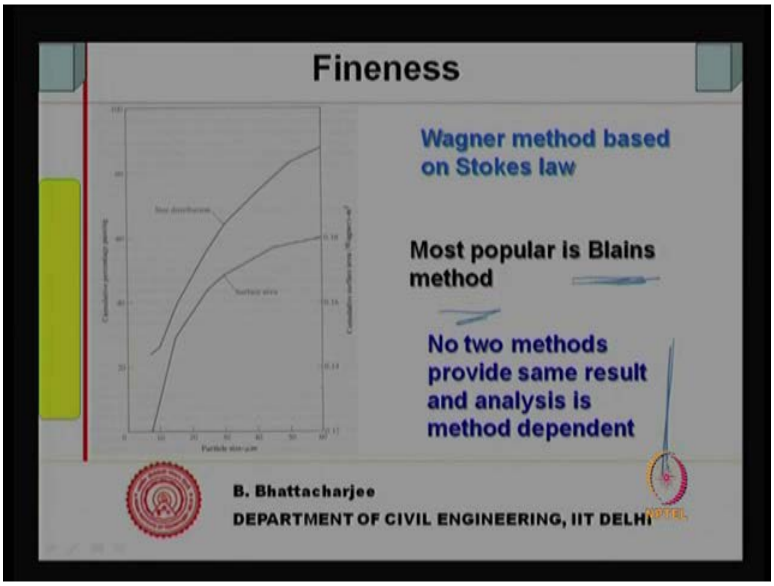

So, let us see what is, what does this gives, but before that it is important to mention that no two methods provides same result and analysis is method dependent. Like time of transition as I said whatever particle size distribution it gives laser deflection do not give the same thing, neither the you know part hydrometer analysis will give you the same thing, if you do it through microscopy no one give the same thing. So, there are problems every method has got the problem, but they can be used for relative comparison. If you use same method two cements can be compared and which cement is finer than the other cement that you can say. So, Blains method therefore, it is most commonly used, because they are very simple method and test can be done in any laboratory without much difficulty. So, let us see blains method.

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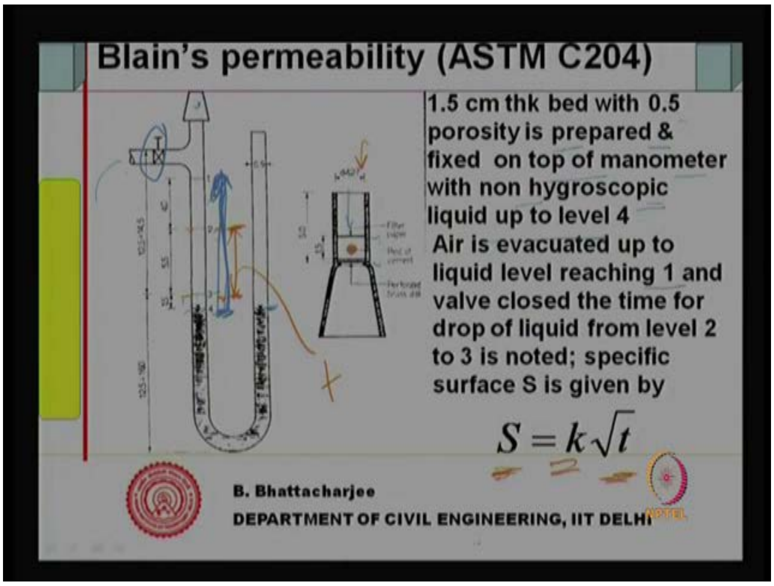


In blain's method what you do is, you have actually a perforated brass disk here, a filter paper and here this bed of cement, so this you know this one looks like this, this bed of cement it is packed in a given manner with a plunger, you know this in this one we put a plunger puts fix quantity of cement put a plunger and this volume is fixed. So, it is approximately assumed that it will have 50 percent porosity.

So, cement particles are packed in standard manner to have a particular amount of words in them, porosity and then this is this placed here, this placed here it has got a perforated brass disk it is, it is placed here, there is a filter paper here, so nothing will go out and put the plunger from top, nothing will come out of the filter, so put the plunger on top and fix this dimension 1.5 etcetera etcetera and then put it here, it is fixed here.

Now, you have got a nanometer, this is 1.5 centimeter thick bed with 0.5 porosity is prepared and fixed on top of a nanometer with non hygroscopic liquid up to level 4, to this level, to this level, at this level, at this level, at non hygroscopic liquid is filled, now usually it is kerosene, so fix it up this level, you know this filled up to, initially it is filed up here, this distance is marks are there 321 etcetera, let us see.

So, what we do is, we can you know the distance are also available, you know how much is the head would be, so what we do is after you place it here, simple by simple section by simple hand manual suction. So, you can you can suck this air of it such that this liquid moves up to 1, this liquid moves up to 1, you know air is evacuated up to liquid reaching 1. This is simply done manually by using a small, small pump you can say as you know, like the horn of the cycle rickshaw or something like that, you just you just all may be suck it by mouth or something of that kind, so simply this is evacuated such that this manometric liquid reaches 0.1, usually it is kerosene or something of that kind, right?

I mean non hygroscopic liquid which will not absorb water, not kerosene, sorry fixed, not kerosene, but some liquid which is non hygroscopic and then it is put to 1, just suck up to 1, so evacuation vacuum is created. Then close this valve, close this valve, close this valve and note the time of fall of this liquid from, note the time of fall of the liquid from, note the time of fall of the liquid from, note the time of fall of the liquid from 2 to 3, so from here to here 2 to 3, so note that time the time required. So, what you call, what you do? You suck it up to this or evacuated such that this liquid reaches here.

Then it will start falling the moment it reaches here you put on your stop watch and stop the stop watch at this point time is noted, this time root over of this time is proportional to specific surface. There are some formula empirical formula long it in you need not to look into that, but this is proportional to k under root t, you can understand physically. You know if you have larger surface area, so while if it is larger surface area, then friction offered to the flow of air, because from here to here you can actually pump the liquid up, the liquid will fall, because air will enter from the top, air will enter from the this, air will enter through this.

Now, to enter through this the entrance where the quantity of time required for air to cause drop of this manomatric liquid from 2 to 3, 0.2 to 3 or reduction of evacuation from 0.2 to 3 by 5.5 centimeter is, actually this from 2 to 3 will depend upon permeability of the cement bed here, permeability of cement bed here. If it is more permeable, if it is more permeable, then if it is more permeable, you know it will depend upon the surface area, larger the surface area, larger the surface area time required will be more, if it is more permeable time required be less, if it is less permeable time required will be more. Now, when it will be less permeable? When surface area you encounter this large, when surface area than encounters is large.

So, surface is proportional to under root t, larger the surface area from the cement here, the air has to encounter while moving through this, moving through this it will take longer time, surface area is proportional to under root t.

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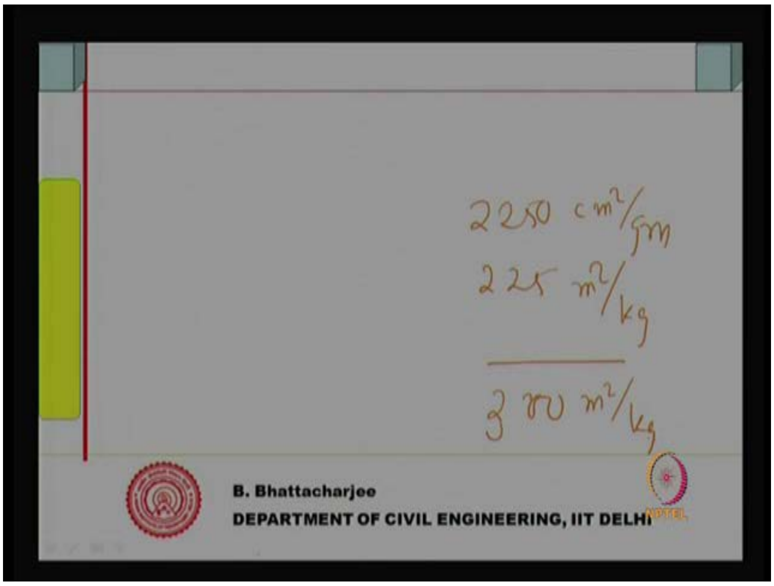


So, this is how we find out Blains surface, minimum specified for ordinary port line cement is 2 2 5 0 centimeter square per gram, 2 2 centimeter square, 2 2 2 5 centimeter square, centimeter square per gram minimum or 2 2 5 meter square per Kg, right? Most of the cement will have something like close to know 300 etcetera meters square per Kg. So, most of the cement will have these values, will come to this sometime later on.

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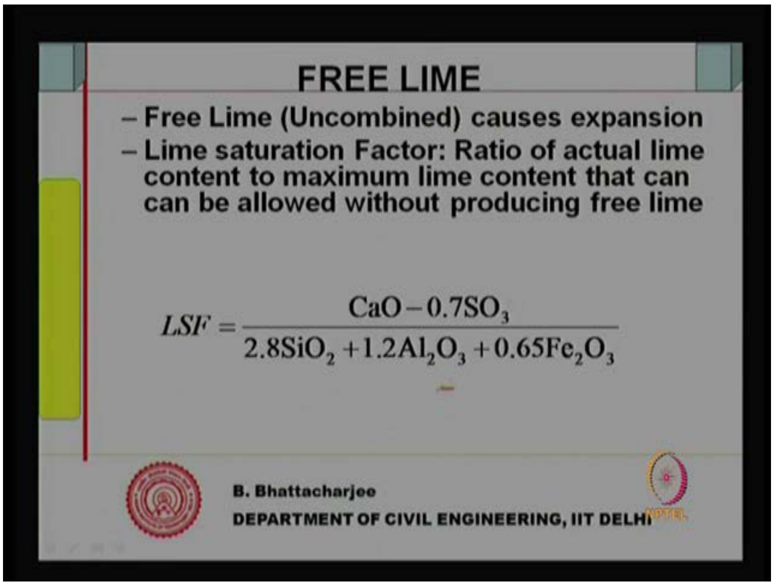


Now, let us see how to determine free lime cement, free lime causes expansion and we have defined the lime saturation factor as ratio factual content to maximum lime content that can be allowed without producing free lime. Remember that we discussed and this lime saturation factor also this equation, we have discussed at earlier in the context of cement production.

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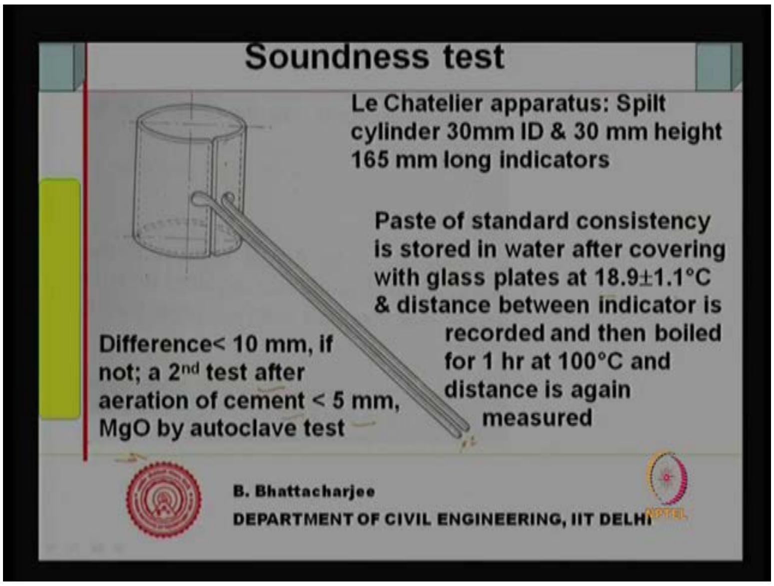


So, free lime is an important issue, because more the free lime I will have, cement will have unsoundness, so soundness of stress of cement is related to free lime, soundness test of cement is related to free lime or free Magnesia. This is tested using Le Chatelier apparatus which is nothing but a split cylinder, split cylinder which is nothing but a split cylinder with 30 millimeter inner diameter and 30 millimeter height, so unit diameter 30 millimeter and height is 30 millimeter and it is 165 mm long indicator.

So, it has got two indicators, this is a split cylinder and there is a split here and there are two indicator here, so what you do? Paste of standard consistency paste is stored in this ward, is stored in water covering with glass plates and distance between this indicators are measured. So, you make paste inside this mould and cover it with glass plate at 18 degree centigrade, 18.91 degree centigrade and after that you measure, so allow the hydration to progress measure the distance between these indicators. The distance is measured, is recorded and then it is boiled for 1 hour at 100 degree centigrade and this distance is again measured. If the difference is less than 10 millimeter, difference less than 10 millimeter, it is fine, if not a second test after aeration of the cement is done and then the difference should be less than 5 millimeter.

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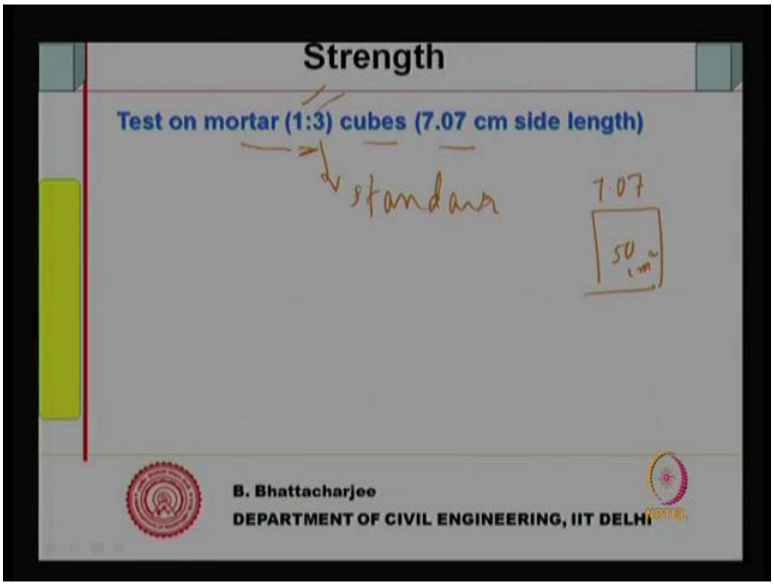


Magnesium, so this is how soundness is measured, so free lime available it will cause expansion, because it will become slaked lime and it will cause an expansion, soundness test, common soundness test is done by this. Magnesia, test for magnesia free magnesia is done by autoclave test, so you put it under pressure under high temperature, cure it at high temperature and using the autoclave test you can determine Magnesium, not very common, but these test is relatively common.

Strength of cement is done, not directly, because cement is never used as mixed cement and again this test is a means for comparing two cements, it does not give us. You know you where compare to strength potential of two cements, strength potential of two cements, not really anything to do with the strength of cement or cement paste, hydrated cement paste not really. We are interesting finding out the strength potential of cement as a material.

Hydrated cement paste is strength, you know we are not trying to look into the micro structured gel strength is nothing, this is the tool for comparing on, this a test method for comparing two cements their strength potential in concrete system it will be this is so, so what we do? We test actually water cubes for compressive strength, so we use test on water 1 is to 3, 1 cement, 3 strength and strength is standardized, strength is standardizes, so that standard and cube size is 7.07 centimeter side length, in other words 7.07, this will be 50 centimeter square.

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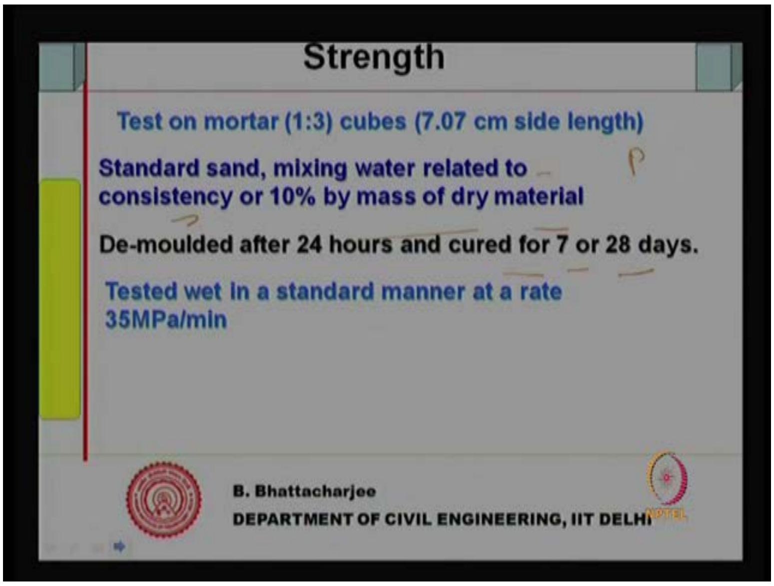


So, you test 50 centimeter square cube and cast them in standard manner, mixing water it is related to consistency by a formula or 10 percent by mass of dry material, total dry material, close to you know cement and 10 percent by mass of dry material or in some course it is related to P standard consistency. So, then this is cast this is cast de-molded after 24 hours and cured for 7 or 28 days, this casting is done in a standard manner, even compaction is done in a standard manner.

The vibration has to been standard mould, standard by vibrating machine, everything else is standard use standard cement, I mean a cement standard, only cement is a variable, quantity of water is fixed by the code related to consistency or as I said some cases 10 percent of the mass 10 percent by mass dry material and then de-moulded after 24 hours and cured within at a fixed temperature, specified temperature for 7 days or 28 days and then tested wet, tested wet in a standard manner at 35 MP of rate of loading per minute, so at a fix rate of loading.

Because all this affects the strength of those cubes, the rate of loading and material itself will depend upon you know hydration extra will depend upon curing condition. So, fix the curing condition and temperature is fixed, temperature of curing is fixed, temperature of casting is fixed, casting is done in a standard manner, only variable is cement. So, you can compare two cement, the strength positional in concrete by this test, although it is not necessary that we have higher strength cement, you will get the proportional increase in the strength of concrete that is not necessary. But this can compare to cement and you can have specification of cement based on this tests results, so if you have higher strength it will have higher potential of strength.

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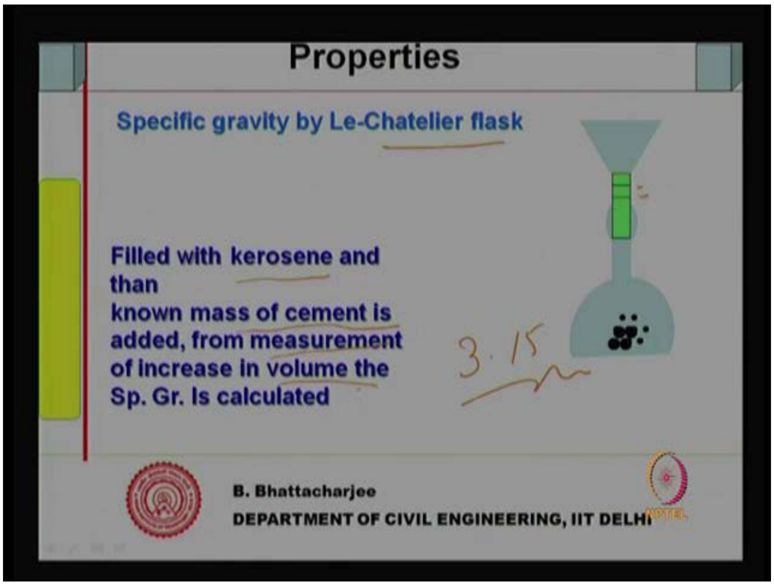

Specific gravity is measured by Le-Chatelier flask which looks something like this, which look something like this and we put first liquid something like kerosene, which do not react with cement and the increase in volume is what is observed, there are graduations here, so you put the cement first the liquid fill it up, then put those solids, see how much is the increase the volume, this is weighed fixed mass. So, what you are doing? First at this Le-Chatelier flask is filled with kerosene, then known mass of cement is added from measurement and increase in volume of is found out.

So, by from increase in volume, volume of the cement is found out by driving air bubbles, you drive out all the air bubbles and find out you know, how much due to by putting this solids here in the flask which are filled with liquid like kerosene before, how much is the increase volume? So, this volume of this particles are measured, its mass is known, specific gravity we can be found out, typically it is 3.15, typical it is 3.15, the value is 3.15 or close to 3.1.

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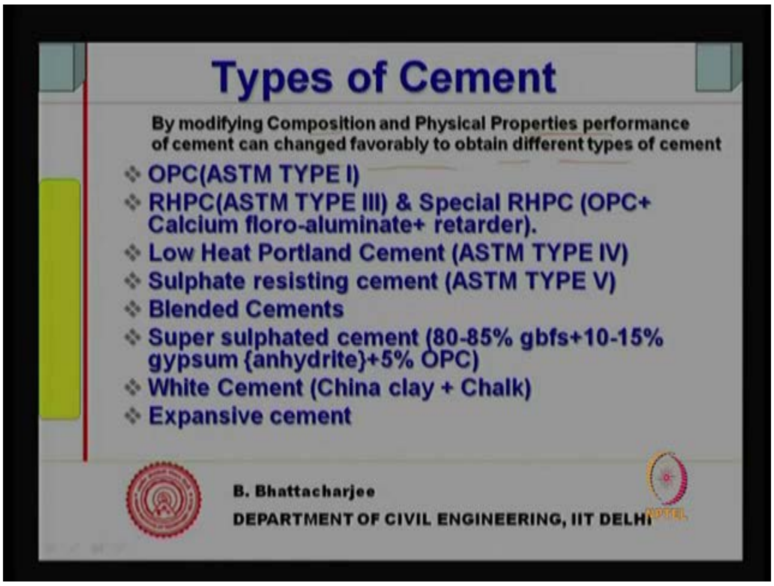


So, I think this is say what largely we wanted to discuss today, but I will discuss types of cement in the next class, because what we know is a hydration process is a function of the compound composition. Depending upon type of compound hydration will progress at a faster, amount of compound, which compound has how much quantity, because we have seen C 3 h is responsible for higher strength, similarly C 3 a is responsible or of high heat of hydration. So, if I manipulate the composition of the cement, properties can be altered, so when you discuss type of cement we will discuss this. So, we discuss this from this slide in the next class that by modifying composition you know and physical properties, because physical properties means fineness for example.

So, by modifying physical properties and composition and cement the properties can be changed favorably to obtain various types of cements and this is what we will discuss in the next class. For example, OPC is a first type of cement, RHPC is the second kind of cement rapid hardening port land cement, ordinary portland cement, low heat portland cement, sulphate resisting cement, blended cements of various kinds and super sulphated cement, we will discuss all of them white cement, so many other expensive cement which will expand and various other kinds of cements.

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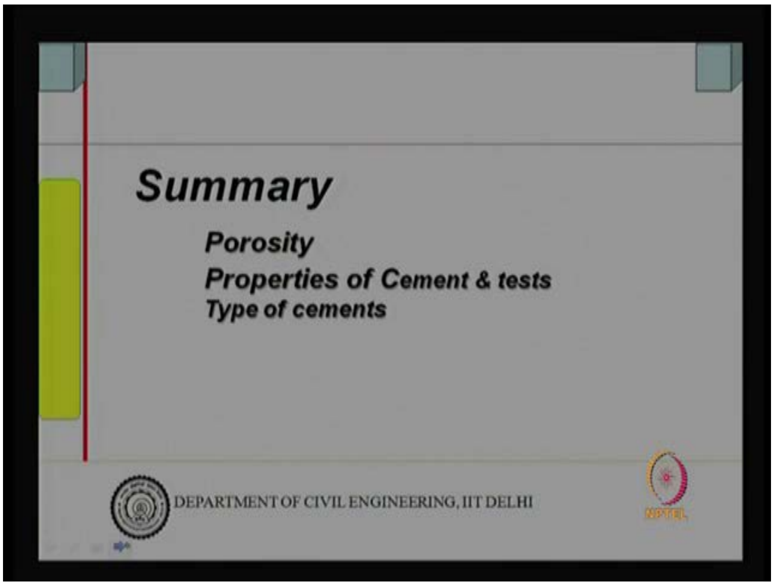


So, I think with this you know this would be the composition I will look into this in the next class. So, with this you can summarize types of cement will discuss in the next class, we have actually discussed to the porosity which you could not do in the last class, so we continued it from there, discussed the various formulae, derived various formulae for porosity. Some numerical problems can solve easily on those, I really did not solve any numerical problem, but simply you can find or estimate the porosity using these formally. Then we also looked into some properties of the cement and corresponding tests and we introduced you types of cements. Next class we will look into the types of cement in details. So, thank you very much.