Sustainable Materials and Green Buildings
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Lecture - 18
Recycled Aggregate – ITZ and Processing

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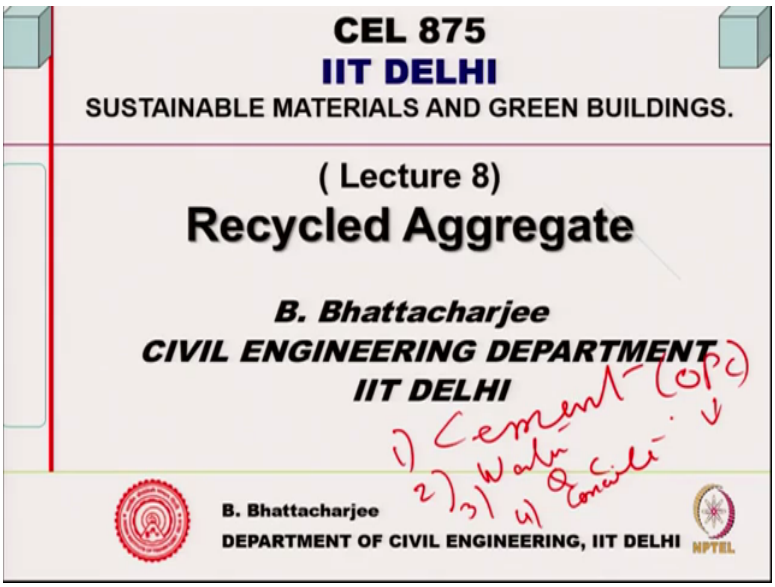

Having looked into cement as a first thing right, we looked into cement. Having looked into cement, cement first we looked into cement, OPC their reduction and all that to make it more sustainable. Then we looked into water reduction, quality control and somewhat related to concrete system, it just related to concrete system. So one of them was if you remember natural resource depression in terms of aggregates.

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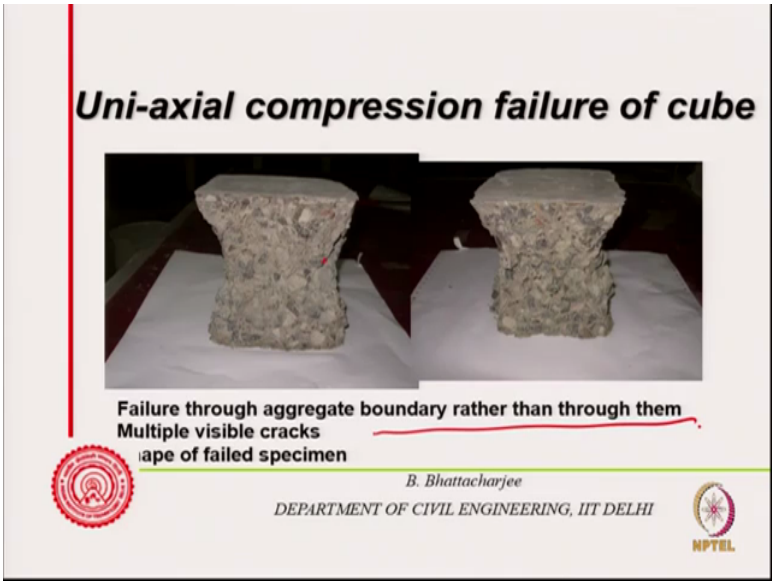

Now therefore, we should see how the aggregates you know role of aggregates and how we can reduce it all? Now this is what I show you or telling you sometime related to strength, you will find that failure always occurs with the normal strength concrete. Failures always occur at the aggregate mortar interface. You know aggregate mortar interface.

You will rarely see in normal strength concrete, the aggregate themselves are failing unless you have very weak aggregate system. Right, so this is this shows the diagram of typical. So failure through aggregate boundary rather than you know multiple rather than through them and you will see multiple cracks. So there are lot of cracks. So this is the shape of field specimen.

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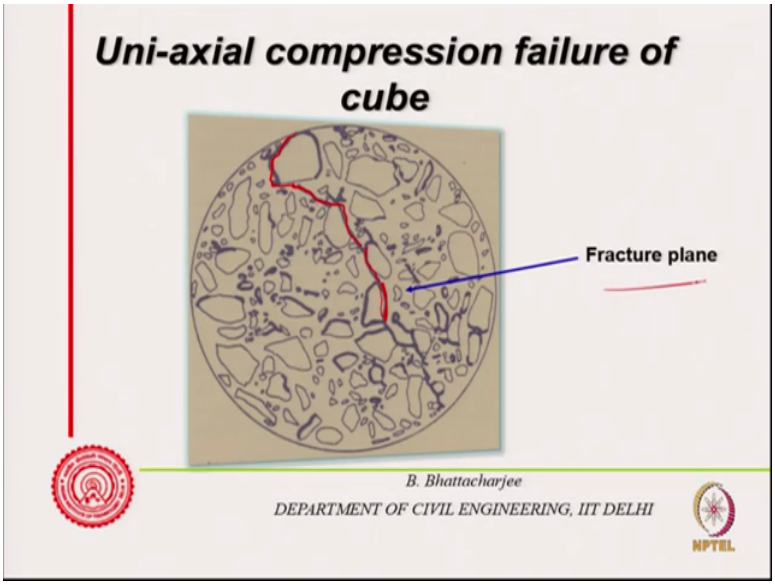

So what actually happens is fractures starts from somewhere there. And it will propagate to the next aggregate boundary in next boundary in between there are pores connect through them. This is our fracture progresses I think I showed some time to those who did actually concrete technology course fracture plane is something of this kind.

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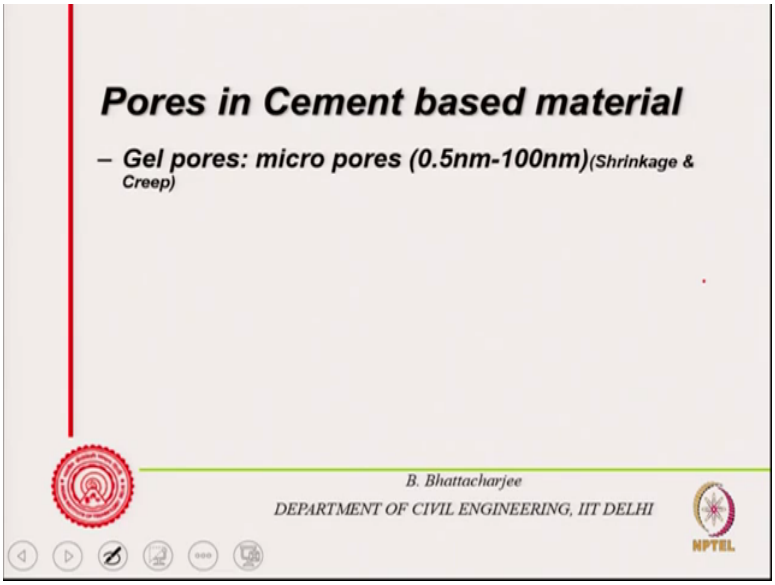

Now you see essentially as I said failure takes place through weak point. Okay, I do not know whether I have a slide here. ITZ I will come to but we have a slide I think I do not have because I am not talking too much about the strength here but still those who have not done a course of that, for them, see the strength of such system starts from strength of such system if I calculate out.

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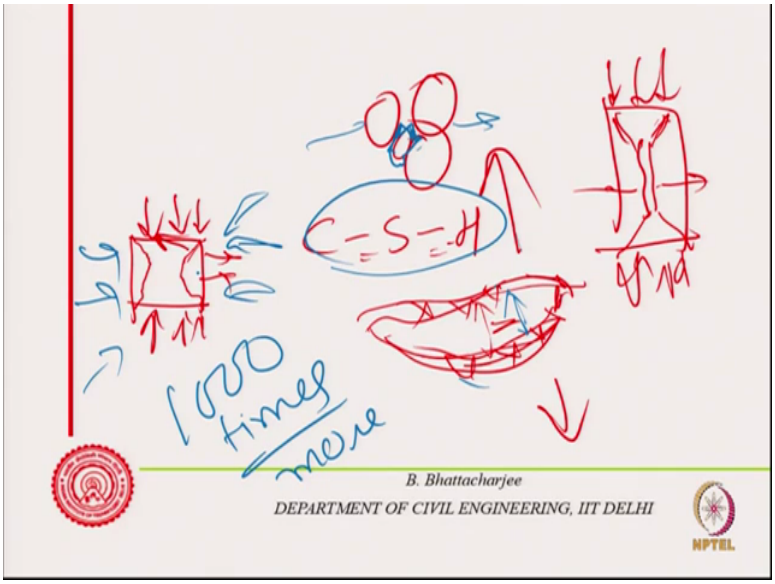

For example I know the calcium silicate hydrates, look at page 2 only. So these bonds are the layered structure something like this. Layered structures something like this. You know these are kind of model people think. See each is layered structure and these bonds are covalent bond. Now if there is a one layer one sheet of this CHS another sheet of CHS between them

there is gel, you know this is gelatinous structure so we call it gel water and their bond Van der Waals bond exist between the two. Right, Van der Waals bond exist between the two.

So, this one if I want to calculate out the strength, strength means am trying to pull them let us say because separation of the material this pull. Shape of the cube failure if you look at it you have applied load like this, right, and you had a shape like this. Failure shape or something like this.

Right, that means some force must have separated the material in this manner some force. So if I take a long cylinder that is better am not going to this now, long cylinder I will get in fact except for the small portion here I will get fracture like this you know crack it would be something like this failure shape would be something like this except for small portion here. As if something is pulled it out along the another direction that is the (())(4:15).

So failure of concrete under any (())(4:18) compression is again failure actually due to tensile stress in transverse direction because it is weak intension and you can understand this very easily because these are particulate material you have bonded with some binding material. You have bonded with some binding material. This is bonded with some binding material. Right, and which are not very strong, the bonds are not chemical bonds.

They are mechanical bonds with the aggregate interlocking sort of roughness. And in this, therefore, when we try to pull them this separates out. So, the essentially tension they are weak. They are strong if you try to push from all sides triaxial test, triaxial test you do to the cube. They have simply get compressed after that nothing will happen it can take lot of load.

Normal stress, just the normal stress you increase share strength also increases you might be have studied in soil mechanics so therefore basically in uniaxial compression means failure intension. So, pull is dominant one. Pull tension which will cause you know. So If I look at CHS this one and look at this pull, now this forces I can calculate out the Van der Waals force how much it will hold it on theoretically, how do I separate or even you know all those bonds strength if I try to find out and calculate out theoretically I will find the strength to be more than 1000 times than what we realize.

More, 1000 times more than what we realize actually we see in this kind of condition. Basically because there is flaws in the system, their weak points, and this is why is not only this fracture of material occurs this is for brittle material, even for metals flaws of their, that is

why you get all kind of deformation, (())(6:28) relationship and so on. So this comes with the material flow. So weakest link governs the strength.

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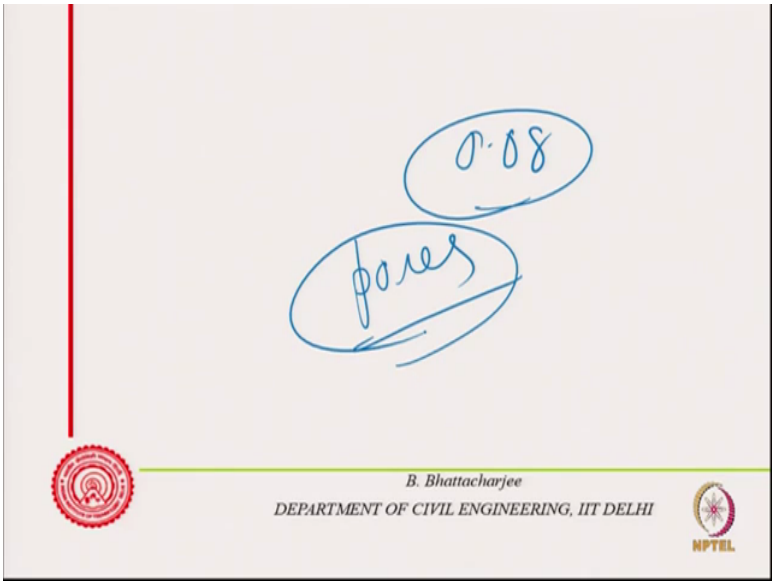

And what is a weakest link in this kind of system? Pores. Because pores are inherent to cement hydrate system or this kind of particulate material system pores are inherent actually, inorganic bonded system if you can remove them, strength will be very very high. That is why Abraham got so much of highest strength 0.08 water cement ratio. Practically you no water very little water coating only on to the cement particle and it you know reaction would have occurred, reaction was taking place and at that time we apply the lot of pressure.

So there actually all the particle get bonded together. Unhydrated cement because there would be lot of unhydrated cement if you have so much of water. This unhydrated cement itself get bonded with the hydrated. Now you try to pull them it is relatively difficult. It could take lot more load. So that was the idea. So these are the weak points in the system. Right, I might have some equations there sometimes later on.

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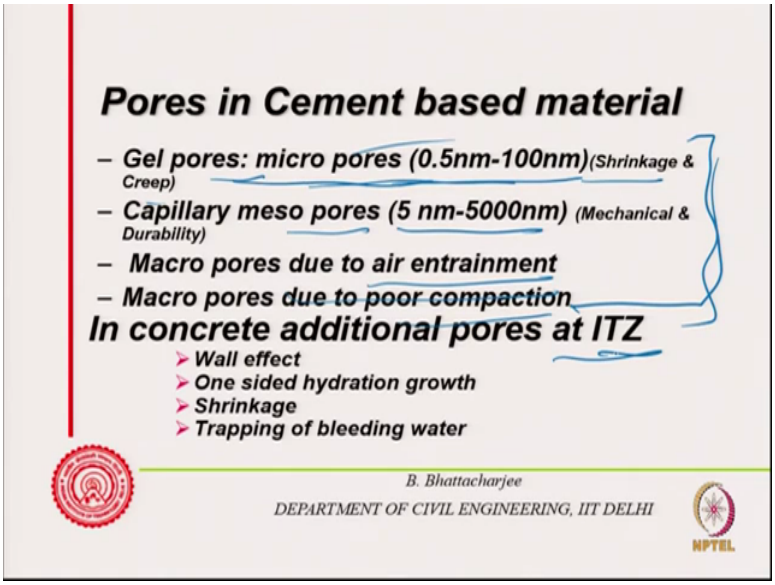

So pores in the cement base systems in fact in geopolymers also you will have pores. Although you are no using opposite link. Every all of these inorganic system because whenever you are adding water to react and solidify, all the water you know if it is consume and space fill by water if it is fill by that solid product then you will have no porosity. But usually that will not happen.

If you are using polymer system, resin and or monomer some form or resins which will get polymerized to higher molecular weight and solidify even there if there is shrinkage of the polymer itself we will get new pores. So reaction process tend to or sometime you can packing etcetera etcetera you might there might be already pores existing in the system. So even polymers etcetera but generally polymer have got highest strength.

That can blow holes air pockets inside, so they are the weak points actually. So that is why pores in cement based materials are important because they govern the strength and ofcourse durability too because if they are interconnected as we talked about segmentation sometime earlier then if they are interconnected aggressive L agents from outside may come and penetrate into it.

So the pores are important from larger pores particularly capillary pores are important from the strength as well as durability point of view. So these type of ordinary portland cement cleanker system or portland pozzolana cement. These types of micro pores have been identified for a call gel pores as I showed between the CHS layers, this is a gel pores, shrinkage and creep they are responsible for.

Capillary meso pores these are the sizes mechanical strength and durability they governed. And if you have air entertainment deliberately you are putting air for durability purpose for (())(9:23) resistance purpose I will not discuss this, you can have larger pores also or there can be some pores because of poor compaction. If you have poor compaction this type of pores may occur.

So therefore in phase this kind of pores you will get, right, pores in cement based material. But in concrete you get additional pores at the interfacial transition zone. You get additional pores at the interfacial transition zone. What is interfacial transition zone?

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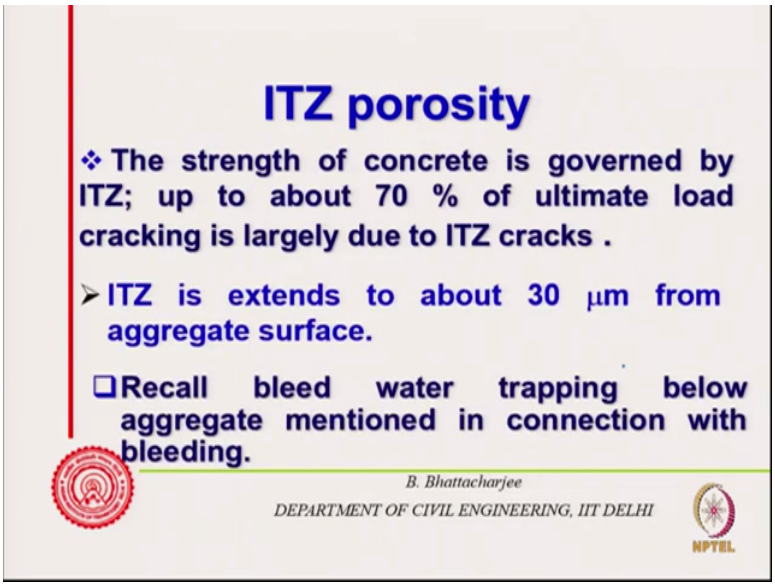

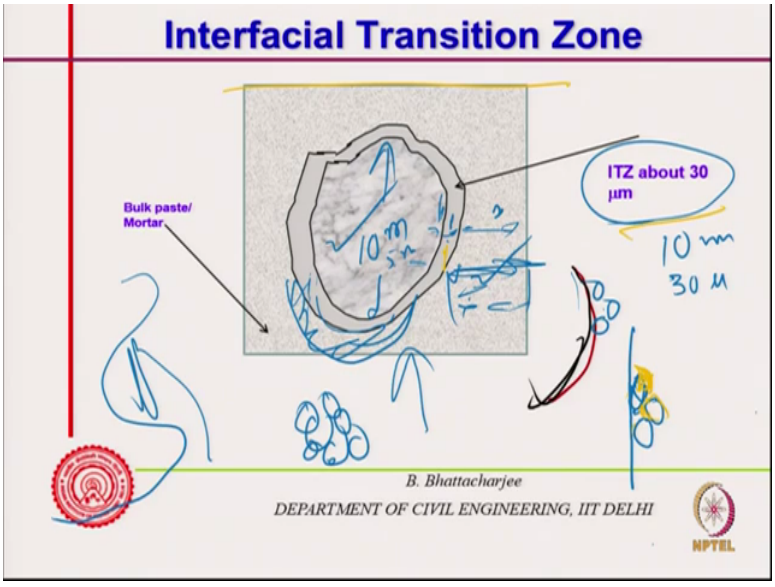

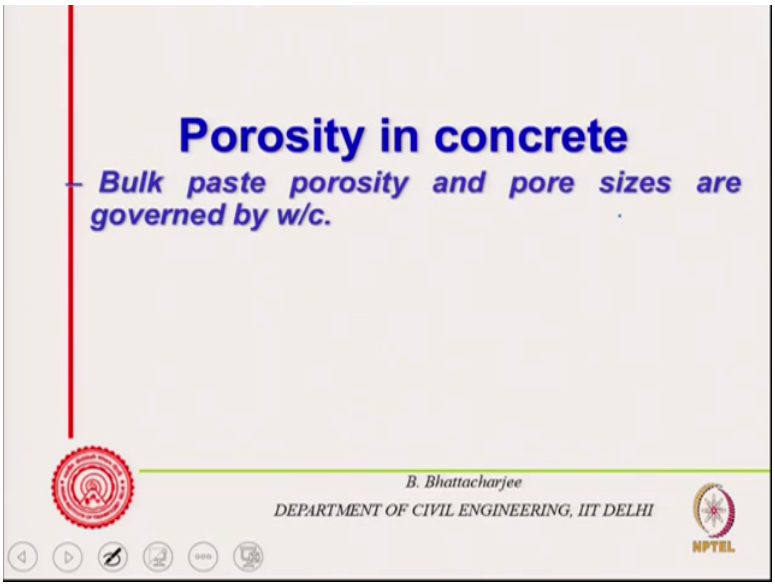

I think I have a diagram, so I will come to that and then go back again. Supposing this is my aggregate, this is my aggregate. This is boundary you know at this boundary near this boundary and these are my paste system let us say. This zone properties are different than this bulk paste and this bulk aggregate as well.

Right, why? Because I think next diagram here, ITZ this is an around 30 micron. 30 micron also people have actually measure. Now let me see if I have bulk paste or mortar, if I have some more, no, okay. There is let me explain it here then I will go back. Now, why this comes, if I take this portion and enlarge it let us say, enlarge it a little bit. Enlarge this what have been the color, enlarge this portion, this portion then cement particles will pack here, cement particles will pack here.

Packing is never very good near the wall. Cement these sizes are, this will millimeter size. You know 10 millimeter let us say 5 millimeter coarse aggregate depend it. Cement sizes are micron, cement sizes are micron 30 micron, 40 micron, 50 micron lesser than that. So micron sizes material here, so therefore the ratio you can see 10 millimeter and let us say or 30 micron.

So this is 1000 times smaller or 100 to 1000 times smaller. So this particle is just like a wall as if you are putting something in front of a wall and packing there is never the best. This is called Wall Effect. This is called Wall Effect. Near the wall particles, otherwise in the bulk they will paste like that like this. In the bulk they will pack like that like this. Here the wall is there. Sometimes you know this would block its going goes to the wall.

So, this is Wall Effect. Right, so Wall Effect is one of those effects which causes this. So therefore the properties are here the packing is not as good as this. Cement particle packing will not be as good as this. So this have something called Wall Effect. We have something called one side this shrinkage effect because cement paste (())(12:20) you know, so this side it will try to shorten, this will try to shorten, while this is not going to shorten.

So this whole bulk tends to shorten, so there will be shrinkage at the aggregate do not shrink, paste shrinks so there for shrinkage due to shrinkage there could be some separation occurred. The third variety is the water, bleed water if excess water is there water might get trapped here at the aggregate interface. Water you know has a tendency to come up. In cement concrete system water is got the least specific gravity.

So it will have a tendency to come up. And this is a regularly shaped aggregate supposing I have an aggregate of this shape something, water can get stuck here also. You know so water gets stuck at the boundary, so Wall Effect, Shrinkage Effect, bleed water trapping as we call it. And also one sided hydration growth, the hydration will not occur along hydration product will grow, hydration product will grow only in this direction mode.

This direction no hydration will occur. This direction here of course both direction hydration will occur. So, one all of them put together, you get higher porosity in a 30 micron zone which we call Interfacial Transition Zone ITZ, Interfacial Transition Zone ITZ. Which we call ITZ.

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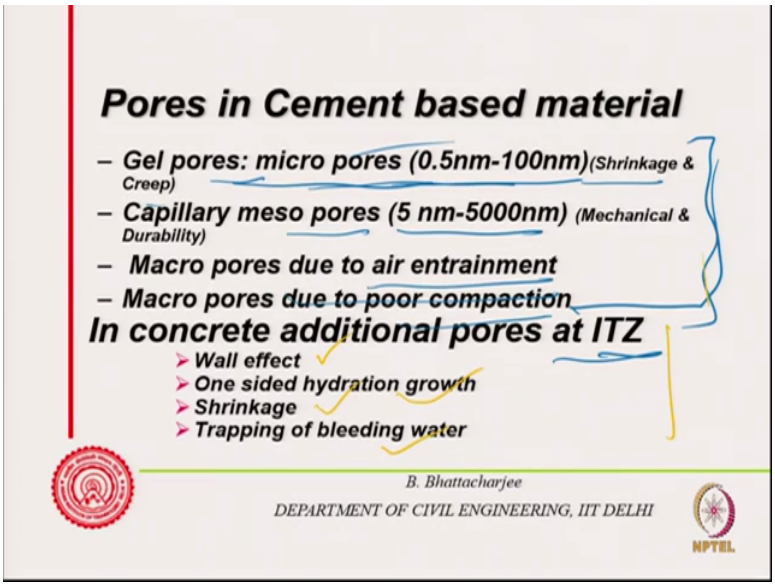

So therefore this ITZ, you know ITZ is a other porosity which is there in concrete. In paste this porosities out there. Wall Effect, one sided hydration growth, shrinkage and trapping of bleed water that is what I have mentioned. So they cause additional porosity at the interfacial transition zone.

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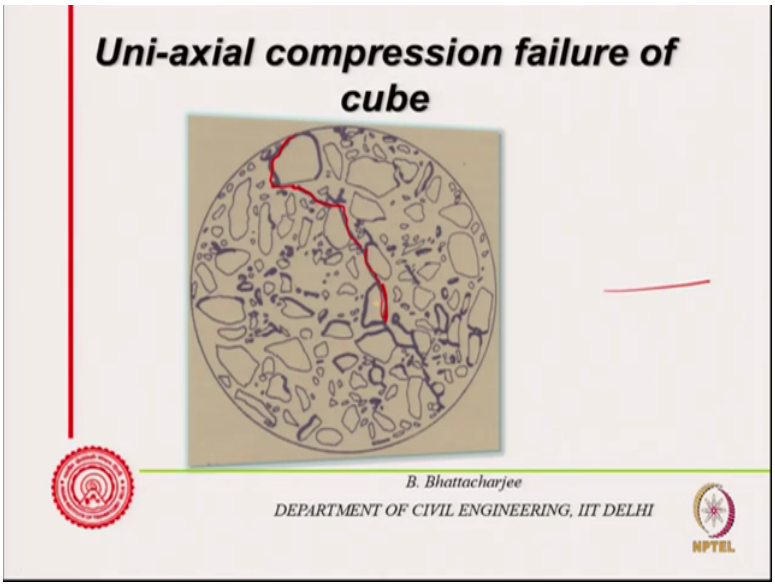

And if you remember, now the fracture part of it, fracture part of it, it starts usually from the interfacial transition zone. Right, in normal strength concrete of course in high strength concrete we try to improve ITZ itself. Because weakest thing governs the strength, so if I increase improve the ITZ itself now may be many things fails together, balance situation. The fracture will start from a pore in ITZ or otherwise and even might be a pore from the aggregate within aggregate itself, because aggregates are not zero porosity, rocks.

So all might start together, so failure is at one point therefore, failure is usually brittle, sudden failure, everything fails together here of course we will see lot of deformation.

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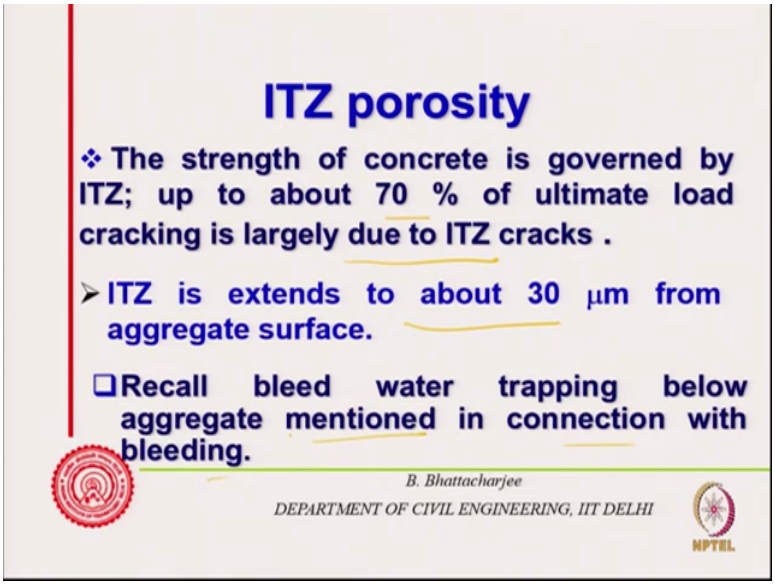

So that is what it is pores, now my problem why, what is role (())(14:51) aggregate, yeah that is call recycled aggregate, that is got a role. The strength of the concrete is governed by ITZ upto 70 percent of the ultimate strength and cracking is largely to ITZ cracks.

This is 30 micron as I said and bleed water trapping below aggregate mentioned in connections, okay am not talking about bleeding now but I will explain you what this is.

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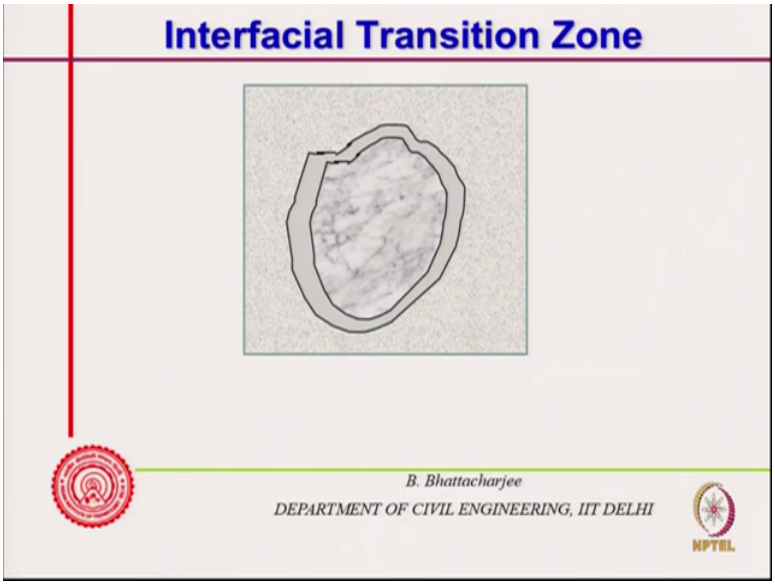

So this is the aggregate mortar interface, this is the aggregate mortar interface right, and that is ITZ.

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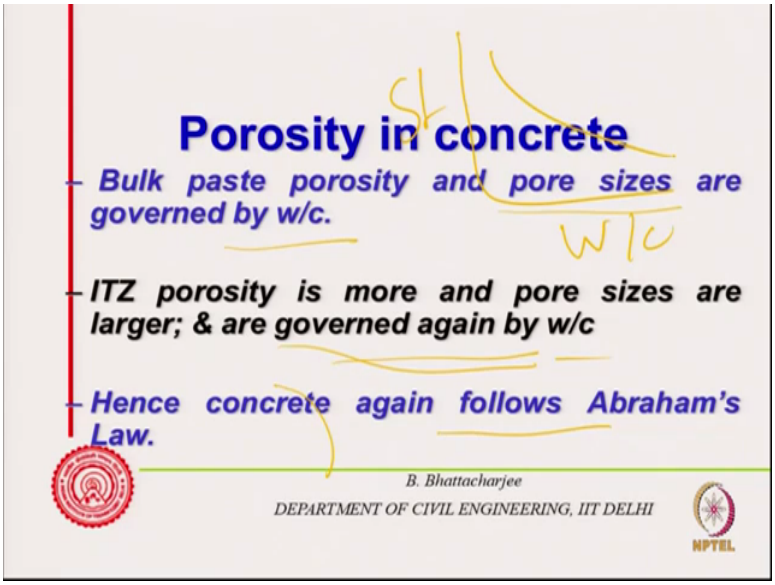

Bulk porosity and pores sizes are governed by water to cement ratio bulk porosity, bulk paste porosity. ITZ porosity is more and more pore sizes are also governed by water to cement ratio. Why? Because if we have higher water to cement ratio at the ITZ itself the water will be more, and they are to be field in by hydration product. So therefore this is also governed by water to cement ratio. That is why strength of concrete is paste is governed by water cement ratio. Strength of the concrete is also governed by water cement ratio. Right, say higher the water cement ratio, strength will be lower you know. Higher water cement ratio w by c versus strength, this is an SL curve what we get even into this case even in concrete. So that is the idea, that is the idea.

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So aggregate now this has got a relevance when you look at the recycled aggregate. Now here what you do is you see this is just aggregate processing. You will find lot of, lot of photographs even in net you will search and their books of course. So, for example this is you know reported by them. So, the first thing is the process is Demolition.

Demolish, Demolish in construction waste I can use them, recycled aggregate is mostly (()) (16:53) construction and demolition waste or similar other products if I can get it from. So this is first demolish then collection. Right, and then taking it somewhere else.

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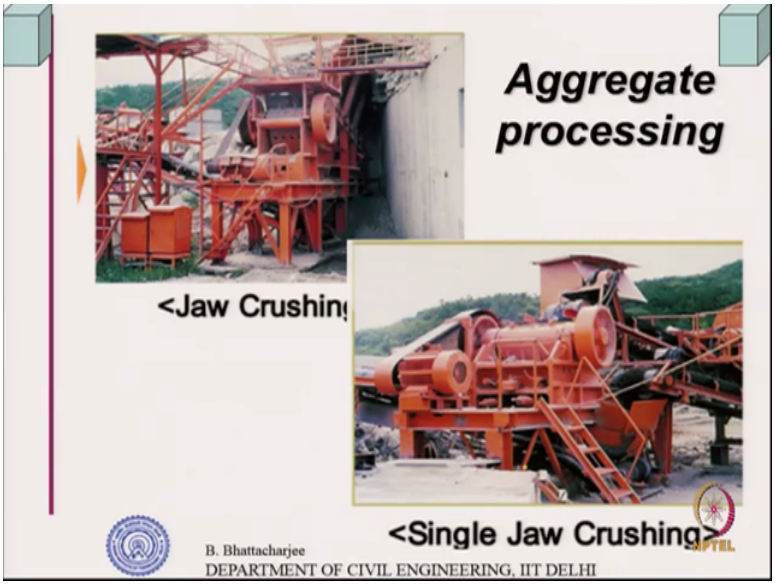

After that crushing using Jaw Crusher. So this is crushing actually using Jaw Crusher. Right, and then Single Jaw Crushing further crushing. Crush to the required size as you have done for aggregates.

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So, then separating using screens larger size to finer size. There can be Cone Crushing after that, so there are several stages of the crushing of this demolition waste in the mean time you have to remove the metals and other product right.

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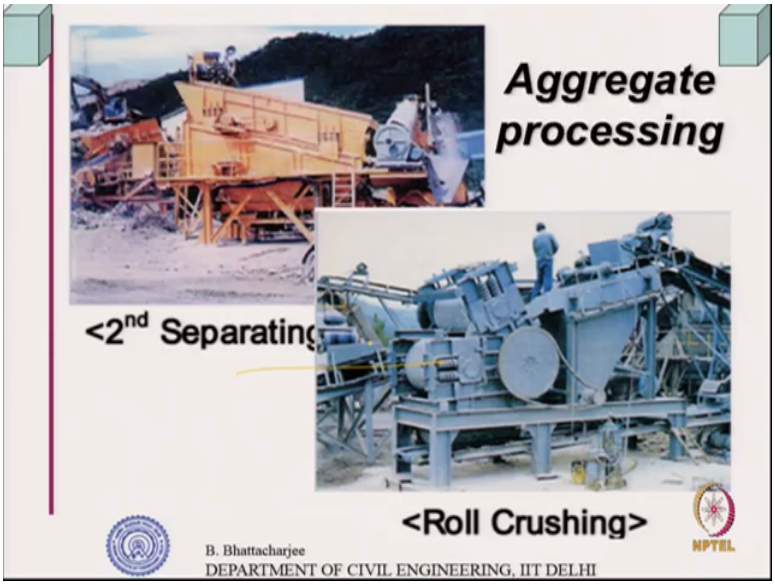

So if you have to remove there are separating screen, there are Magnetic Roll Crushing all these are there. Right, separating and roll crushing separating through screen and fine ones are separated out roll crushing. So this is process actually.

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And then find particle or oil separation finer particle because you know decantation rate of the particle going through the material through liquid Stocks Law differs. So through oil you can do some separation. Air blow separation for very fine particle.

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Magnetic Selector in order to remove metals and then finally you might get recycled aggregate (())(11:22). So from construction and demolition waste they would look like this, look like this. But let us see what are their properties? So that is process they have more.

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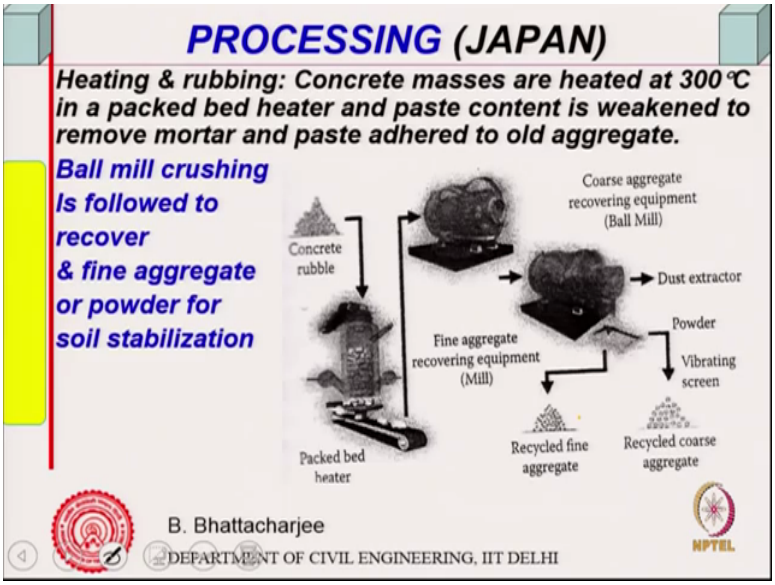

In Japan they do something more. Okay I will come to this later on, I think I will come to this later on but first processing Japan I will to later on but let me go to this one.

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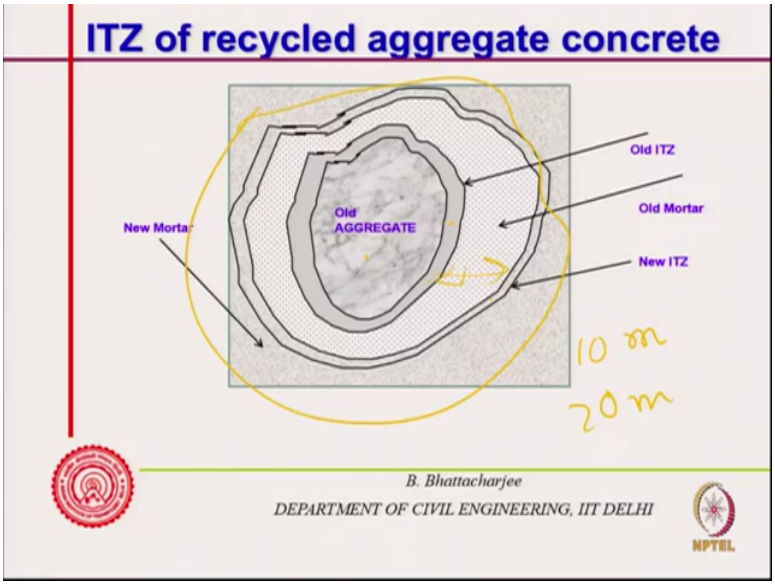

Explain what are stocking about? This I will not go I will going to this no this is Europe classification you know yes. So old aggregate which is (())(19:05), I have got a new aggregate system. After crashing from the old concrete I have got a new aggregate system right, aggregate system. Which will have some old aggregate and is old ITZ. And now the old mortar so the (sorry) the new aggregate, crushed aggregate, recycled aggregate will have old aggregate, interfacial transition zone of the old one and the mortar adhered to it.

Because you have crashed it, now it is concrete which is artificial stone say something like 10mm coarse aggregate its transition zone around and then another may be 12 you know 10 or 7 or 8mm, if it is 20mm down 7 or 8mm of mortar, I mean this is (())(19:59) but it could be something of this kind. So the aggregate of recycled aggregate has got an old ITZ and then mortar adhered to it. And then you will have new ITZ around it when you put it into the concrete.

So now you have got 2 ITZ old and the new. And therefore, the strength is still lower, properties are still lower. Okay. So new ITZ and that is your bulk mortar now, right? So new mortar that you would be putting in so that is the scenario.

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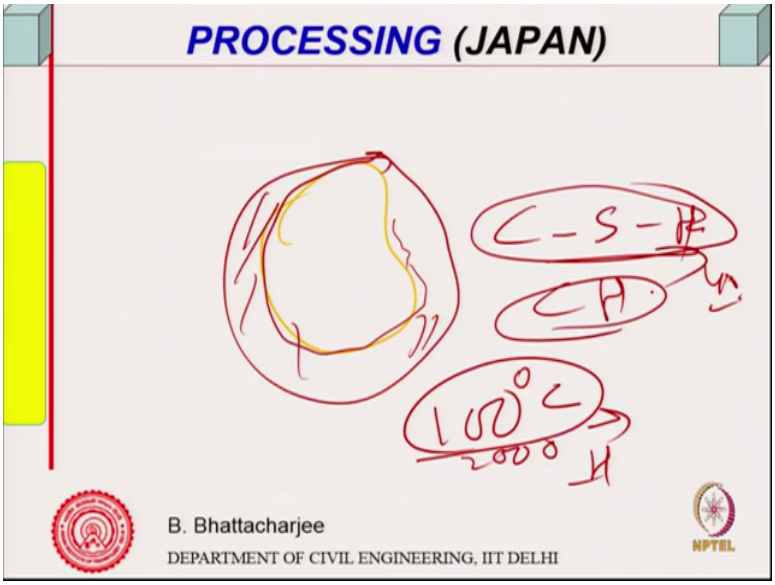

So, let us go back now, I can go back now this is the, this is the one. So that is why what you can do? You got to remove this mortar as much as possible, if you remove this mortar around it, if you remove the mortar around it, if you remove the mortar around it. Okay this color is fine, mortar around it to the old aggregate then it will be better, it will have you know and remove the old including ITZ completely that will be best, now how do I do it?

One thing we know if I heat up CHS system and calcium hydroxide system, CHS breaks down upto a 100 degree centigrade what will happen? 100 to say 200, H will go away. That is your capillary water, that will go away, capillary water will go away from you. But upto 400 degree centigrade or so this will start breaking, and 600 or so you will find that calcium hydroxide also breaks down which means that bonding capability of the CHS will vanish if we heat it up.

That is what happens in fire, when you subject concrete to, you know concrete is subjected to fire or high temperature, we subject it to high temperature, this is what happens 600 degree centigrade you find the strength is very little. 800 you can just scratch it out. So, this therefore, if you heat it up the adhered water will tend to go away. So that is what they were trying and they have tried heating and then rubbing.

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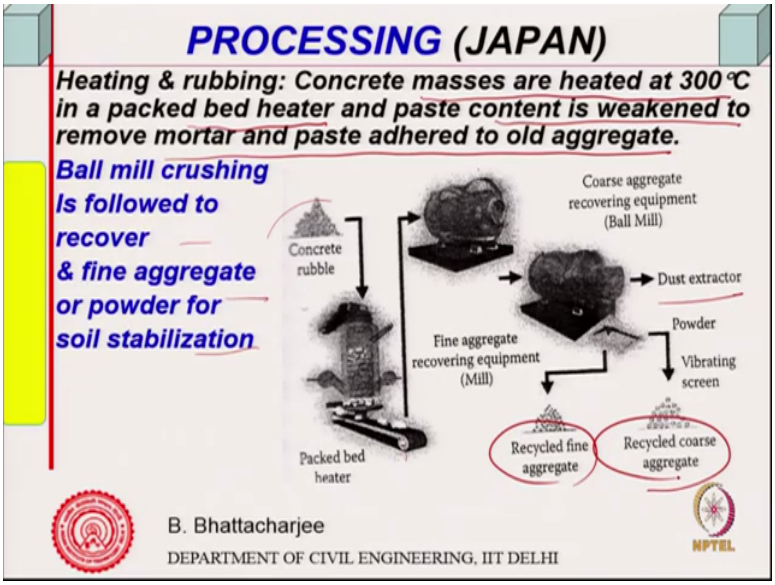

Heat it and rub, so concrete masses are heated to 300 degree centigrade in a packed bed heater and paste content is weakened to remove mortar and paste adhered to old aggregate. So this is a processing part other than getting, collecting, crushing, getting into the right sizes, now this is something more.

So Ball mill crushing is followed to recover fine aggregate or powder for soil stabilization. And this is how the process is. So it is in a packed bed system concrete rubble, this will be heated somewhere in a packed bed heater and then you know the coarse and the fine aggregate will be separated out so fine aggregate would be actually recovered. Dust extractors, so that is what coarse aggregate recovering equipment Ball mill. And recycled fine aggregate, recycled coarse aggregate you can separate it out through a vibrating screen.

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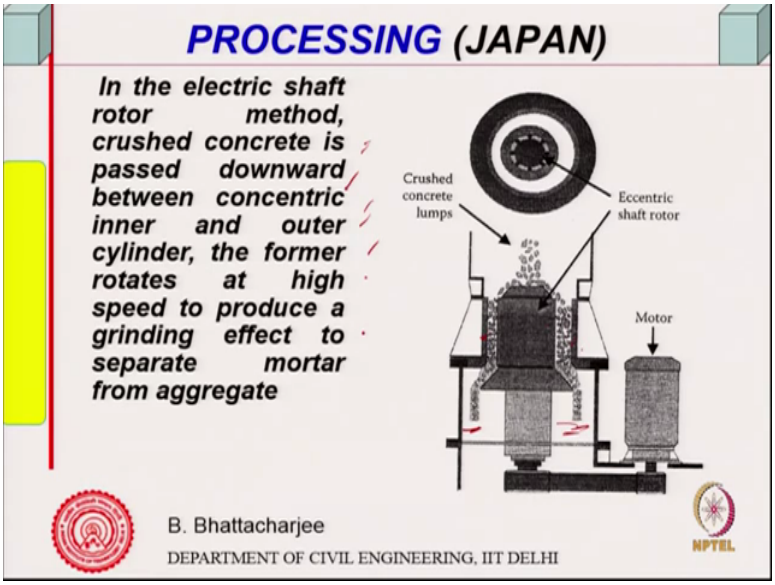

Okay, in that there is another kind of electric rotor shaft method, this is another one same you know process. This is passed downward now crushed concrete lumps are passed downwards, there is a of course a motor which it cause things to rotate and it is passed and this is one side of it Eccentric shaft is there, there is an Eccentric shaft and this rotates and this crushes against the wall, crushes against the wall.

This is an Eccentric shaft which will rotate and crushes the aggregate against the wall therefore, causing some fine particles to come on once, you know fine particle and coarse particle to you know fine particle becoming finer, because it is eccentric shaft so one side it will have more, other side less and crushed them between the wall and the shaft wall. So, concrete is passed you know this, this is the electric shaft rotor method, crushed concrete passed downward between the eccentric concentric inner and outer cylinder, the former rotates at high speed to produce grinding effect to separate mortar from aggregate. So this will separate the mortar as much as possible.

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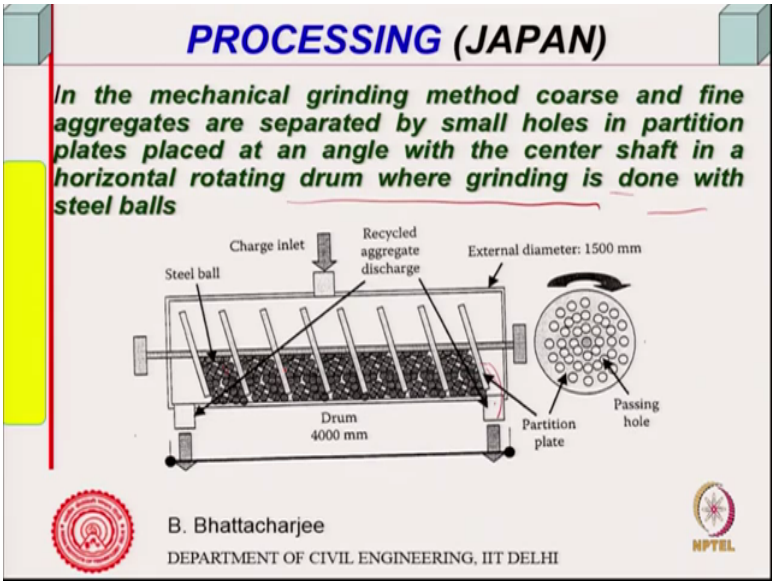

In the mechanical grinding method coarse and fine aggregates are separated by small holes, right? In a partition plates I will show the diagram placed at an angle with center shaft, with center shaft in a horizontal rotating drum where grinding is done with steel balls.

So this is where your drum is, this is where your drum is, right? And there are passing holes are there from this one which will take out so for example this will rotate. Recycled aggregate discharge would take place through somewhere there, through this once right? There is a drum this will rotate and it has got steel balls actually this is the balls so this is the kind of balls (())(25:00) of those steel balls with the aggregate system causes removal of the fine particulate system.

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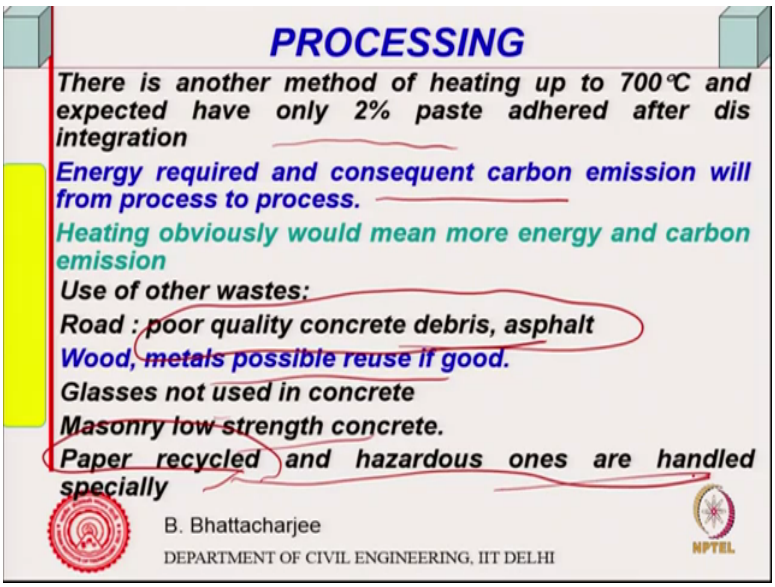

So, there is another method of heating upto 700 degree centigrade and expected to have only 2 percent paste adhered after disintegration you know so that is what it is. Well, now you are heating it to 700 degree centigrade which means that of 600 or whatever it is you are giving additional energy. So energy required to (())(25:28) and then this much be accounted also. This is also high and heating obviously would mean more energy and carbon emission depending upon from where you are getting the energy. So, yes that is the thing.

So, the construction waste and demolition waste C and W as we call it construction and demolition waste, that is been processing is you know is important, and still you do not get the best, there are other ways people have to tried to use it. I think I might have for example what they have tried to do is them get the aggregate, put them, put them in a fly ash water suspension.

So that fly ash actually get into you know they get inside the pores of those aggregate system with the lime fly ash system so try to improve the ITZ. Somewhere you know people have tried this kind of thing or put simply fly ash which is fine might get adhered to mortar in the cement hydration reaction calcium hydroxide produce. So there are several things being attempted.

Other ways are you know poor quality concrete debris that come from the road. Wood, metals, so if you separate out the wood and metal you can reuse them if possible. And poor quality (concrete) some, some of them can use in poor quality concrete, for example not have pavement grade concrete. Glasses are not used in concrete because glass is attacked by alumina.

In alkaline system, you know alumina system glass may not be stable, right? Sodium silicate generally they are, they may not be stable. So alkali attacks generally glasses. Masonry of low strength concrete that you can produce, so not one use you can use, different use you can make different use. Paper recycled and hazardous ones are handled separately. Papers for example, they are recycled. If there are something hazardous that you separated out and handled it specifically.

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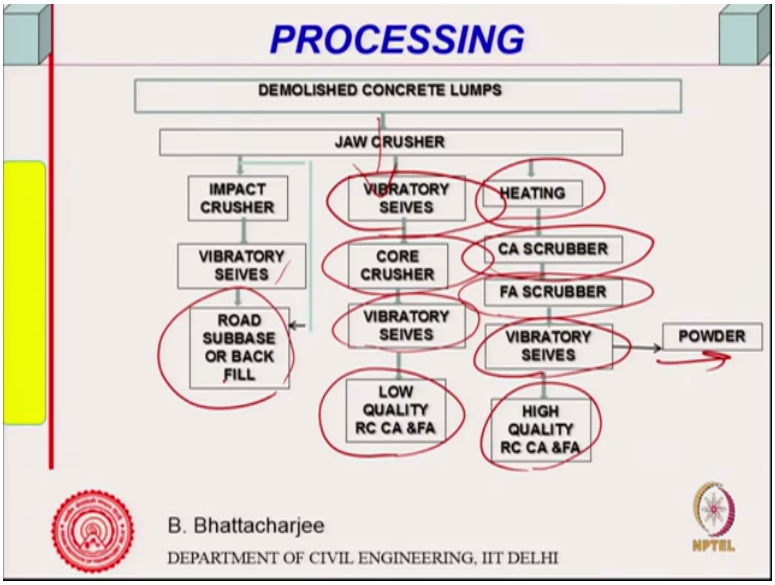

All right, so demolish concrete lumps I think I will stop after processing. Demolish concrete lumps that is why it comes goes to a jaw crusher and then from the jaw crusher it can go to impact crusher, vibratory sieves, this you can use in road subbase or back fill.

And if it goes to vibratory sieves straight away you will get the finer ones then go to core crusher, vibratory sieves, low quality recycled coarse and fine aggregate. And if it is heating is done then coarse aggregates scrubber you scrub it out, fine aggregate scrubber, vibratory sieves, powder or the sand, high quality recycled and (())(28:12). So heating is due to higher quality, vibratory sieves first sieve it out and impact crusher this gives (())(28:19) you can separate out and use them for different uses, right? Different uses.

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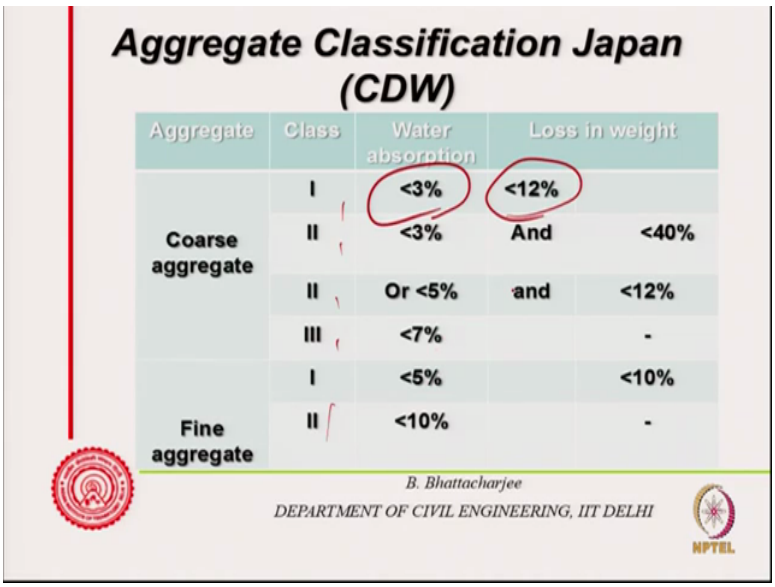

So they have their aggregate classification I will just quickly go through this may be we will repeat in the next class, right? Coarse aggregate for example class 1, 2, 3, 4, 3 and 1, 2 two types 3, 4 etcetera. What you see is properties wise water absorption, loss in weight and you know this is, this is other thing, these are the two things you would see. I just stop may be. You would put it in water there can be loss in weight, absorptions will be there, there could be loss in water.

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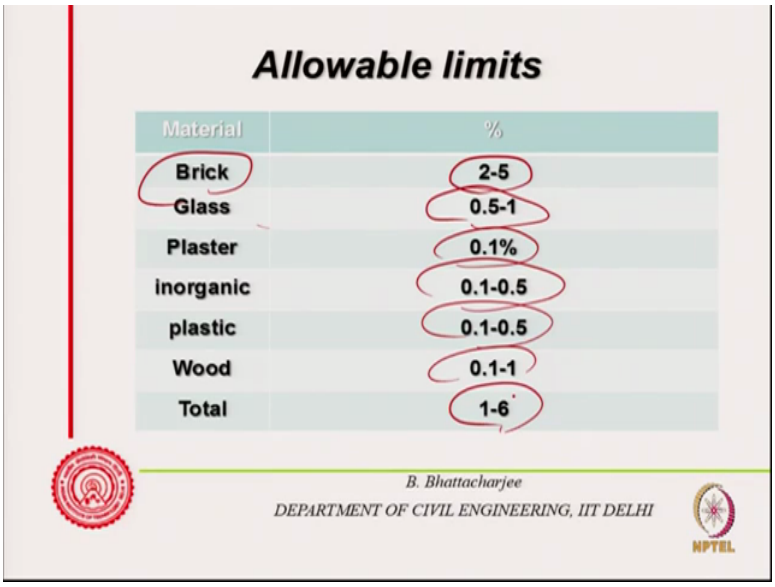

So, these are if it is Brick, source is brick. Construction or demolition waste you cannot allow more than 2.5 percent. Glass, very small quantity. Plaster this much. Inorganic this much. Plastic this much. Wood, total 1 to 6 percent of the impurities can be there, but otherwise it should be all aggregate, right?

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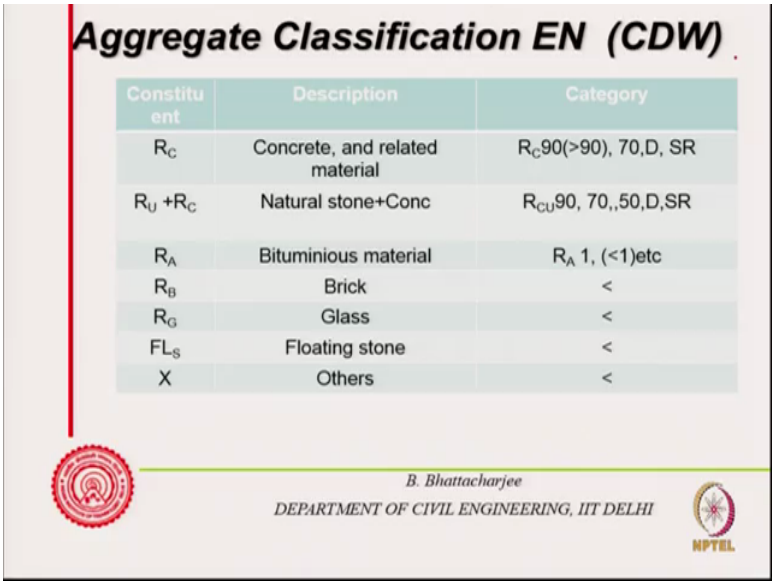

So European code has got their own I think I will discuss this in the next class, right? So, if you have quickly any questions, I would like to answer.