Sustainable Materials and Green Buildings
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Lecture 16 – Curing methods and use of waste water for mixing and curing

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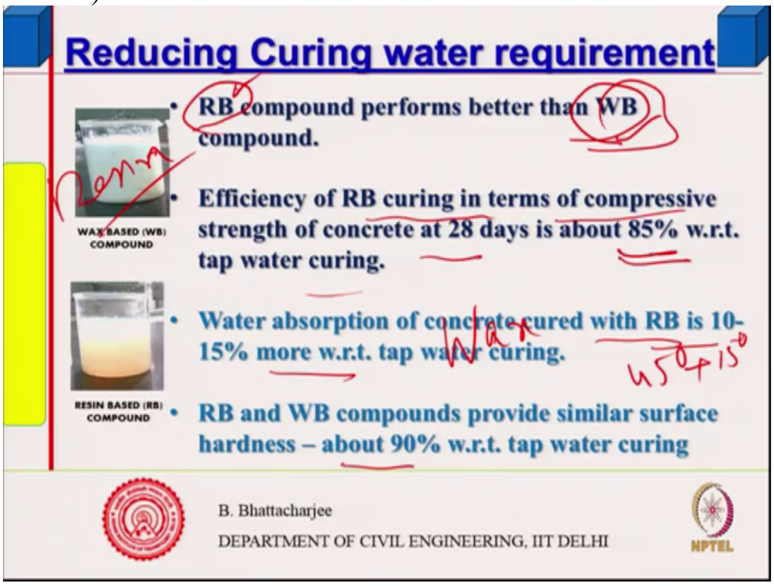

Ok, so coming back to this therefore, we can cut down onto the curing water by using curing compound which are nothing but surface layer. What happens is they block the evaporation process. Do not allow water to evaporate, which is a major component of loss of water, but do not supplement. So you have to actually design the system as I said. There are two types, resin based and then wax based. Wax based, right and these are some kind of other resin based these are commercially available now. Now there would be you know, you can check them or compare them, if you compare this curing in terms of compressive strength 28 days, it will be somewhat less. Strength would be somewhat less. But you are saving onto water, so you might have to use a little bit of more cement in the system, water cement ratio has to be appropriate. So you have to see which one benefits you more, right.

Because 85 percent, you will not get the same because self-desiccation water is not being replenished, right. Self-desiccation water is not replenished. Water absorption of concrete with resin based is 10 to 15 percent more with respect to tap water curing, right. And wax based component provides surface hardness about because then they will make the surface very good. Because luckily the water cement ratio they actually this you know that part no water, water will tend to evaporate out but then it is stuck at the you know, this is contained at the boundary of itself, but this is already after setting. So the overall, water cement ratio change or structure change is not occurring, so generally surface is improved significantly if you use this kind of treatment.

There is one thing one must see these are something like you know these are addition, these are the kind of material which you see. Now there is one more thing you should see, see when we are using this you must see that it is able to withstand the ambient temperature, for example in summer time in climates such as tropical climates say even in the climate of the kind of Delhi which is called composite monsoon climate we have some time of the year absolutely dry, then you have got some time of the year when you have got rainfall and then winter. So during the dry period the temperature goes up to about 40-45 degree centigrade and if radiation is falling onto it the surface it might increase this by another 15 degree centigrade because direct radiation means direct energy coming in, so if you touch the surface it will be hotter than the air temperature.

Now under such situation this must be, these compounds must be stable. Works melt away works can melt away simply peel away from the surface if it is exposed to sunlight and hot air. So May, June if one is doing, one to be careful and in climates for example in desert one has to be careful but then desert water is not available, so you have to design the system appropriately, choose the right kind of compound appropriately, right.

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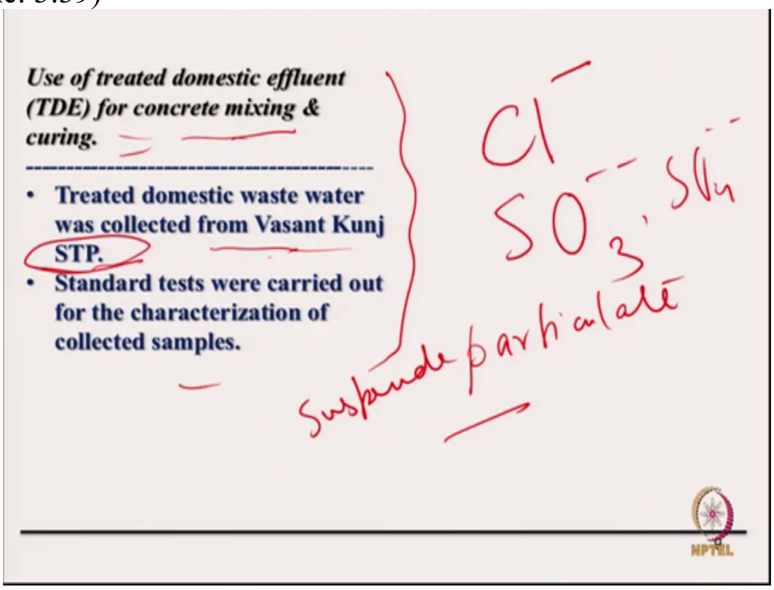

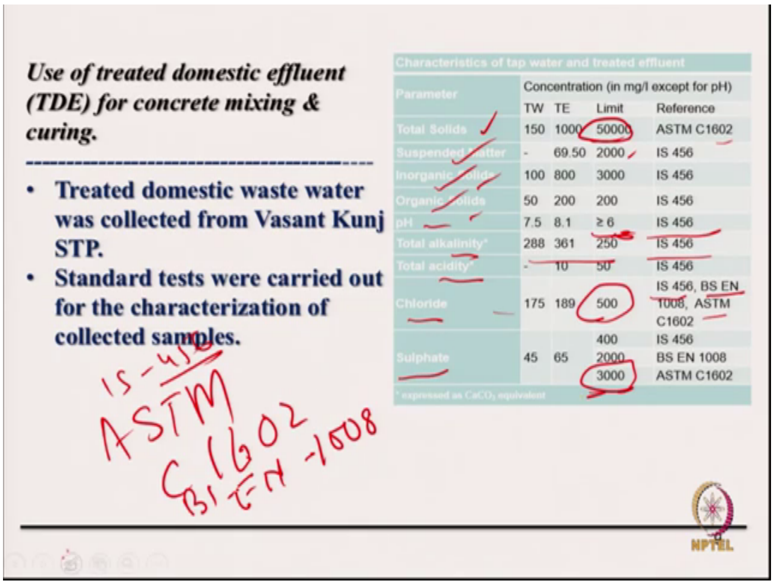

So, treated domestic effluent gives you another advantage, that is reuse of the water that is available, right. So, for concrete mixing and curing both you can use this, treated domestic you can use this both, so the point is the earlier point is that if you use curing compounds or similar kind of things there is some other kind of curing aspect I will talk about. You can have admixtures which you add to the concrete and they can store the water, right. So whatever water I have given they will absorb and release it later on, so this another kind of admixtures, curing admixtures you can use to cure. We will come to that later on but this is, this will be very useful, treated domestic water because otherwise you would have actually put it into the river after treatment also, here it can be used for construction purposes.

Now, ok for example if you collect from STP, treatment plant sewage treatment plant, so you collect from there, then you have to test them for the because drinking water potable water is not necessary for concreting. Human body gets affected by bacteria, the small quantity of bacteria do not affect the concrete but concrete is affected by this SO3. Or you know the SO3, SO4 et cetera, or particulate matter suspended, suspended particulate matter and these are given in standard whether you take American standard of testing material, Indian standard or any standard you will get this standard. So first you test whether they satisfy those requirements or not, right.

So characters, so you just test them. If you test them and just take comparison in a particular case for example this is in, this is parameters are total solids suspended matter as I just said, inorganic solid, organic solid pH okay. So, these are all in milligrams per liter as shown this is an example similar things could be there elsewhere. Total alkalinity, total acidity, chloride concentration, sulphate concentration and this must be total solid should be, there is a limit available as far as ASTM is concerned, this is just as an example. But that is not important, so ASTM limit is something like 50,000 milligrams per liter it should be less than that. Similarly, if you come to Indian standard it gives you suspended matter, inorganic solid, organic solid, pH should be greater than 6 should be, you know but should be too alkaline, right. Too alkaline, cannot be acidic because cement reaction is produces alkaline material and it should not interfere with the reaction process.

So this is as far as Indian standard is concerned, this value is given 6 to 8 and total alkalinity, now chloride content is given by IS 456 BS CN ASTM. Everybody gives this chloride and this quantity 500 milligram per liter is one of the limits actually, so you will find ASTM 6 ASTM C1602 BSCN or EN 1008, IS456 of course gives you.

So, you have to see whatever limits you are you know whatever code you are using it must satisfy, ok, right. Similarly, sulphate the other one. So sulphate and the other ones and these values are again given, they are not all same, different codes have different values, so it must satisfy this requirement and once this satisfied test has been done, then you know for example one can these manually collected scenario and one can collect this.

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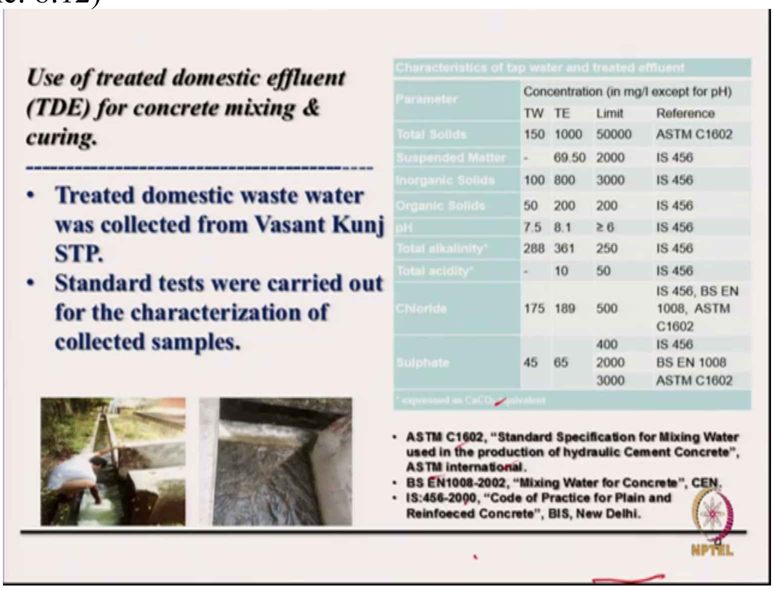

So standards, this STM as I said 1602 BS EN 1008 and Indian standard 456, so this is European, there is American and Indian, so you can look into this and they must satisfy this.

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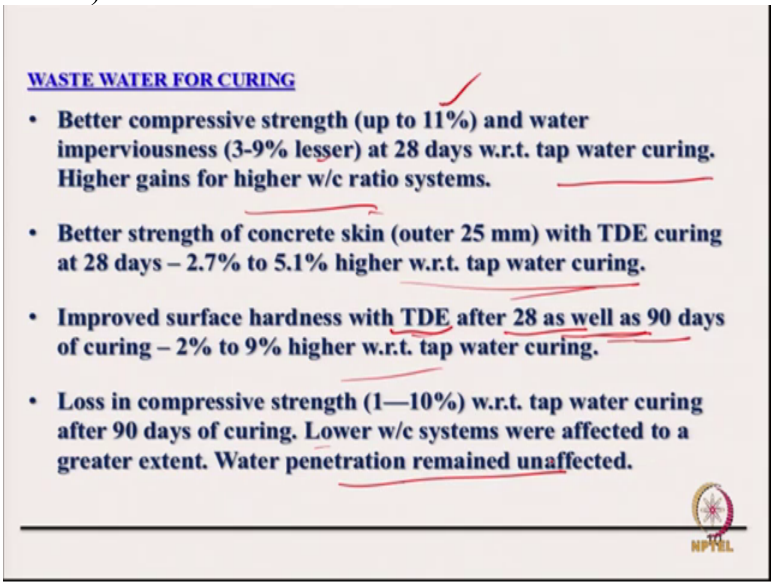

Once they satisfy this, you can sometimes get better compressive strength and water imperviousness also at the surface with respect to some local tap water curing. So, higher you know highest strength then could be somewhat even higher, better strength for concrete skin if one test them through various kind of testing. It is possible to test only the skin performance through something like surface hardness tests, cutting what you call doing what is called kepo test at the surface, cut and pullout test.

So there are various test available, you can actually find out the property of surface concrete while your standard specimen is cube specimen, cube test might be similar, cube strength must be similar but surface concrete you find that pipe you know it is what is important from durability. So, that is what it is and then you can find, this is one example, empirical result somebody might say no, this is not there but it would be within not large variation. That means what we are trying to point out is that treated domestic waste you can always use, treated effluent you can use actually collected from STP you can use. So, this is what it is, treated domestic effluent and 90 days strength et cetera et cetera. So this is one case. So, water penetration or all other properties if you look at it, concrete there you might find it better.

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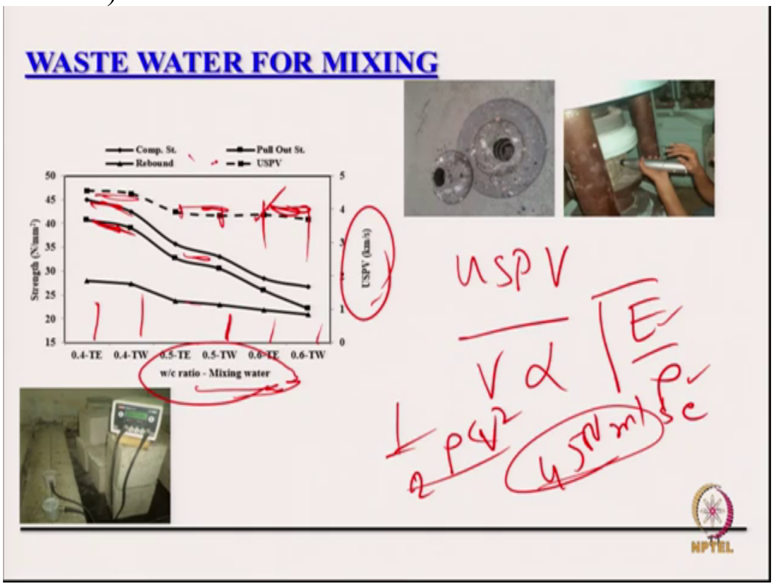

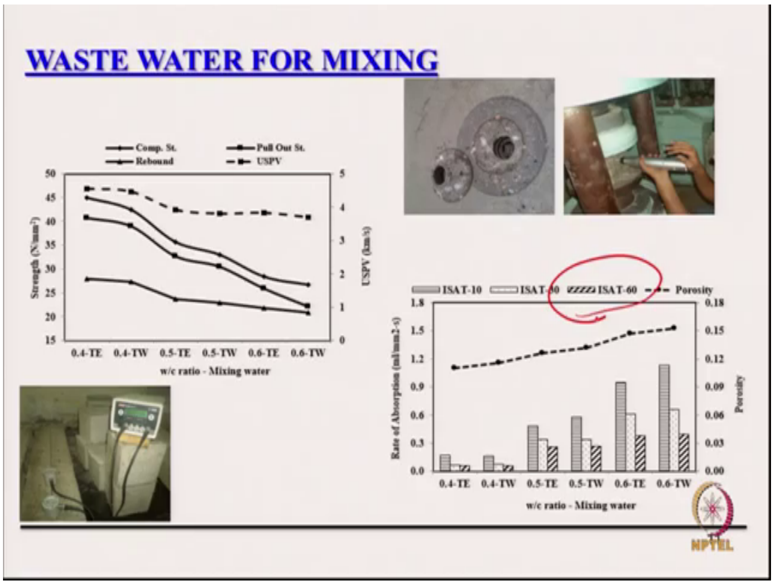

This is what is called as kepo test, cut from the surface, right. And if you look at it water cement ratio of mixing water, this gives an example this is ultra sound pulse velocity is you know velocity is of sound in mechanical, velocity of mechanical waves is proportional to under root E by Rho, velocity of mechanical wave in a solid media is proportional to bulk modulus divided by density. In fact the formula is straight forward but I do not think I need not need to go into. Because when mechanical waves travels in a solid medium there is compression and rarefaction, therefore that would be related to the stress you know the strain, so sound pressure or mechanical wave pressure, the stress deformation is strain, so it gets related to bulk modulus and it is related to density because acceleration is mass, force is pressure is also, so velocity you know half rho V square would be the energy.

So anyway I am not going into this, I am not going into this, so basically velocity is function of, denser the material more is the velocity I mean less is the you know E over Rho, bulk modulus is more velocity is higher. So, ultrasonic pulse velocity we do not use within sonic range, we use ultrasonic because of the dimensional issues, wavelength issues actually. Velocity of mechanical wave in the concrete would be of the order around 4,500 meter per second and dimensions of the specimens you know, so at least one wavelength must be contained within the aggregate, largest aggregate and also there should not be you know all other phenomenon occurring, diffraction and such phenomenon.

So therefore dimensions, this ultrasonic suits very well from that point of view other than creating noise, ultrasonic will not create noise. So, ultrasonic pulse velocity is the measure of solidness of the concrete. If it is more solid you will have higher velocity, so this is what it is. So, if you can see that mixing water this is treated water, treated effluent, treated water you know, so these diagrams are different 0.4 treated water, treated effluent, treated water, so they are comparable. Ultrasonic pulse velocity is comparable, this is for effluent, one of this is for effluent and another one is for treated water, this is for effluent, this is for water, so they are comparable. Similarly, strengths are not very significant. Just you know comparable, so all these properties that you see they are comparable to comparable properties for treated effluent or treated water because tap water would be quite often treated.

And similarly various other properties like surface initial surface absorption test that is a measure for durability and you will find that they are you know the treated domestic treated domestic effluent do not give you worse result. Only one thing you see there are process, different process of treatment, the one which has got H_2S, there are different process that you know the process should not have toxic gases or not toxic really gases or material content which are toxic, toxic to concrete system.

For example, if you have H_2S present in the treated water making it sulphuric acid or something such things should not be there. So therefore you can use treated domestic effluent as long as they satisfy the standards requirement, water requirement, standard water requirement. Bacteria is not an issue, total organic content is an issue, alright so this was related to this was related to use of treated. Now that way you can reduce down on the, cut down onto the water.

You can cut down on the water consumption both for curing as well as mixing. One is one approach is to use the curing compound at the surface that will cut down onto your curing water. Super plasticizer, plasticizer, hyper plasticizers are water reducing agents that will cut down into your water, can cut down onto your cement also. The third approach is used treated domestic effluent as long as the water quality satisfy the requirement of standard codes, they do not seem to create any problem. So you have choices of using all of them whichever is appropriate.

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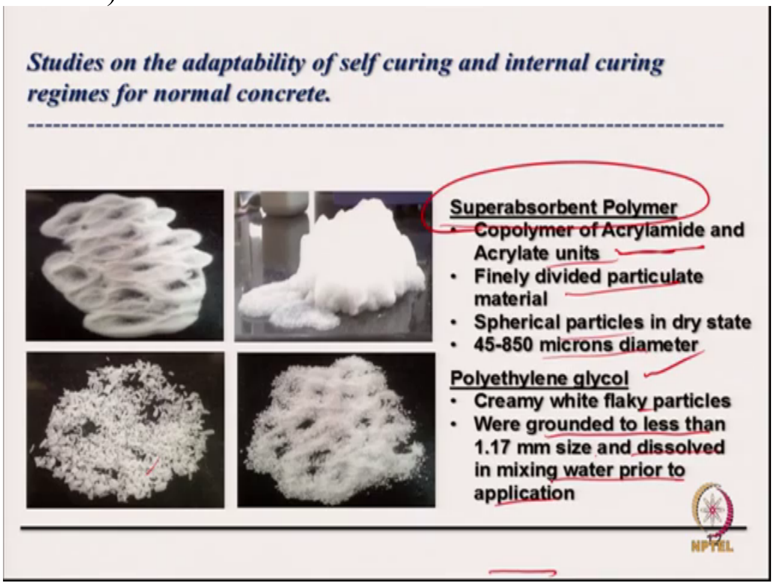

Now there are as I said there are self-curing compound that is you add to the concrete right in the beginning, they will hold onto the water and later on they will release them. So there are 2 types essentially, one is superabsorbent polymer, these are used for hygienic and medical usages also. So what they do is they absorb water, so during the initial you know initial phase they will absorb the water mixing part of the mixing water. Now therefore water cement ratio is reduced during the setting phase, setting means solidification. The structure of the concrete or cement based system forms right at the setting stage because structure will be formed there.

After that the only what happens is the unoccupied space, space which was not occupied by solid, fine space I am talking of because aggregate space is aggregate sustainable, nothing will happen to them. Cement hydrates and the space which was earlier occupied by water or unoccupied space that get filled in. So setting means solidification. Once it has become solid, once it has become solid, no more expansion of the solid will occur actually.

What will happen is it may contract a little bit, shrinkage can occur. So, setting is important, during the setting phase this superabsorbent polymer absorbs water, keeps it with themselves. So, water cement ratio to start with is less than what you have added because polymers would have absorbed some of this and then as the water you know reacts with cement system the vapor pressure will reduce there, there will be vapor pressure gradient existing between the polymer absorbent polymer and the remaining portion it will release the water gradually. So this superabsorbent polymer is one of those admixtures which can be added to the cement based system or concrete system to reduce down the curing water.

So that you have added right in the beginning, later on you may do or may not do so. These are copolymer of Acrylamide and Acrylate units, finely divided particulate material they are generally spherical in dry state, 45 to 850 microns in diameter, would look something like this and there is other type other types are there, polyethylene glycol. This is another one, so this also does the same thing, it holds on the water and releases later on.

So, this you add to the concrete system you know right in the beginning time of mixing and this is a creamy white flaky particle like this where grounded to less than 1.17 millimeter size and dissolve in mixing water prior to application. So you just dissolve them and take that. And they too will not do the job as good as possibly water curing but definitely do a sufficiently good job to cut down onto your water use.

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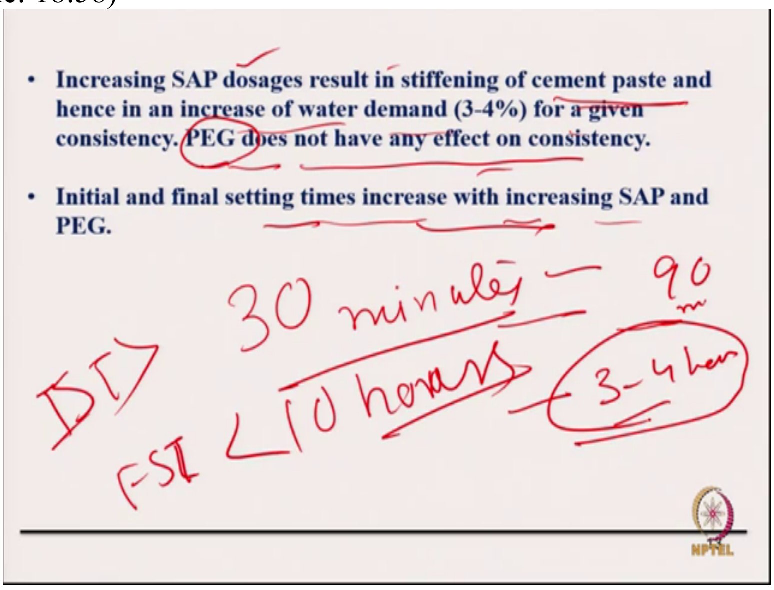

So increasing SAP dosages result in stiffening of cement paste and hence in an increase of water demand. Sometimes some of those SAP that is super absorbing polymer absorbs too much of water, so that will disturb the setting process, stiffens it quickly. So cement paste hence initial water demand might increase for a given consistency. Polyethylene glycol does not have any effect of this one, initial and final setting time increase with increasing SAP and

PEG, so initial setting time increases a little bit which means that solidification process is delayed.

Solidification processes are delayed a little bit. Now what is the difference between the initial setting and final setting? Initial setting is when you know it has achieved such a state that if you disturb it anymore then its properties would be damaged, so it is not fully solidified but form the solid structure, right from the solid structure from the plastic state that it was. And final setting means it has become a stable solid with a definite shape and by large the volume because there can be some contraction so that you can remove the side support you know side shattering, site for more (())(20:18). So, final setting is that. Now usually cements will have setting time minimum is specified is 30 minutes because you want to work, compact, put it into the mold and compact it within that period of time.

So, it is specified that minimum. If I have 100 minutes it does not matter, I will have more time to actually compact it and place it but 30 minutes is the minimum for all cements and final setting time when I should be able to remove the side from work that is 10 hours. So my setting time should be more than initial setting time should be more than this and this should be less than this. Most of the cements what you will find is this is much higher go to even 90 minutes, 1 hour or so and this should be about 3 to 4 hours not even 10 hours. Now these are measured by some empirical tests called beakers test actually, beaker apparatus.

I think I will not go into that but, or by penetration resistance test et cetera, et cetera. Now what does this do? This increases the initial setting time. So, if it was about 45-50 minutes, now it will go to 90 minutes I have no problem. It increases the final setting time, as long as the final setting time is not more than 10 hours I have no problem. Many of the cements will have 3 to 4 hours, so let it increase a little bit but you have to check that it does not increase beyond 10 hours. Then, you will have issues of demolding, then you will have issues of demolding. So these are the effects of, but these materials you can use them.

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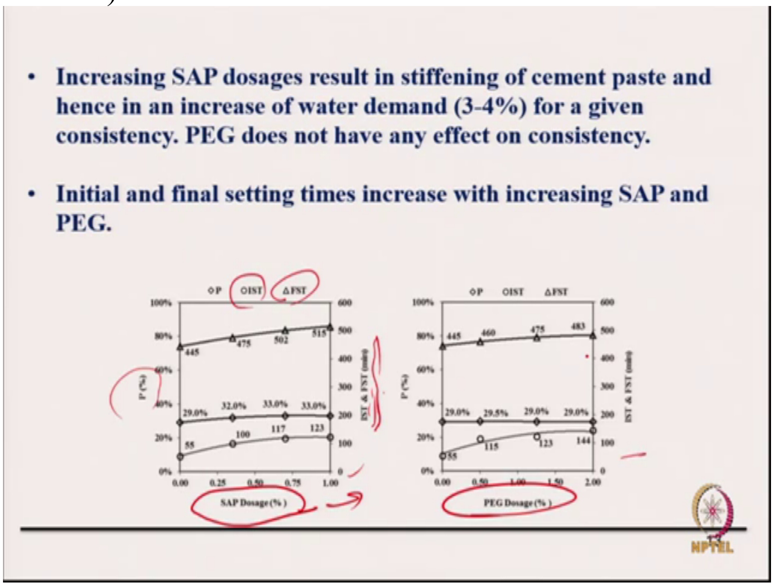

So these are some of those results, SAP doses, superabsorbent polymer doses you know, so this is what you call initial and final setting time in minutes, standard consistency is what is measure, I mean and then you add them and same amount of water and you find out. So, this is what it is, so initial setting time final setting time, this is what is given here. As I increase the dosage SAP dosage to 1 percent or so, this is also small quantity, so this is what happens and this is with polyethylene glycol. So this is the dosage it shows and these are the properties how it will go and that is what it is.

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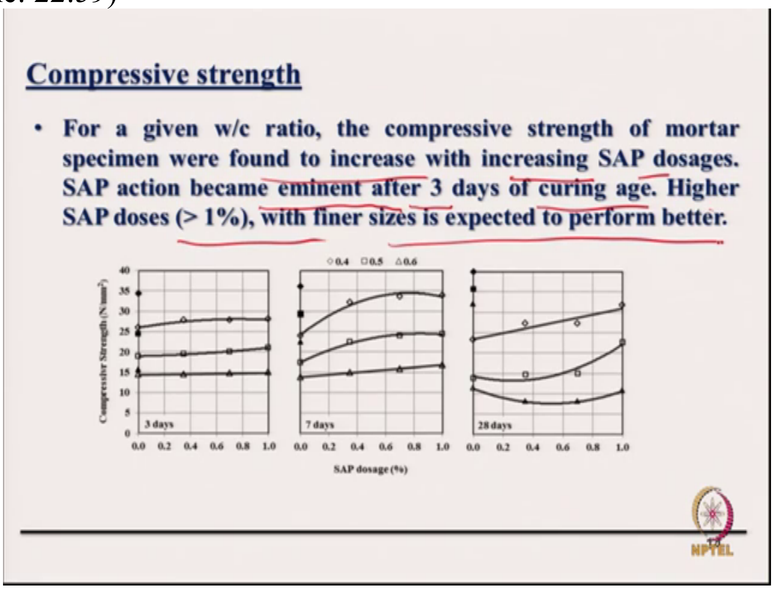

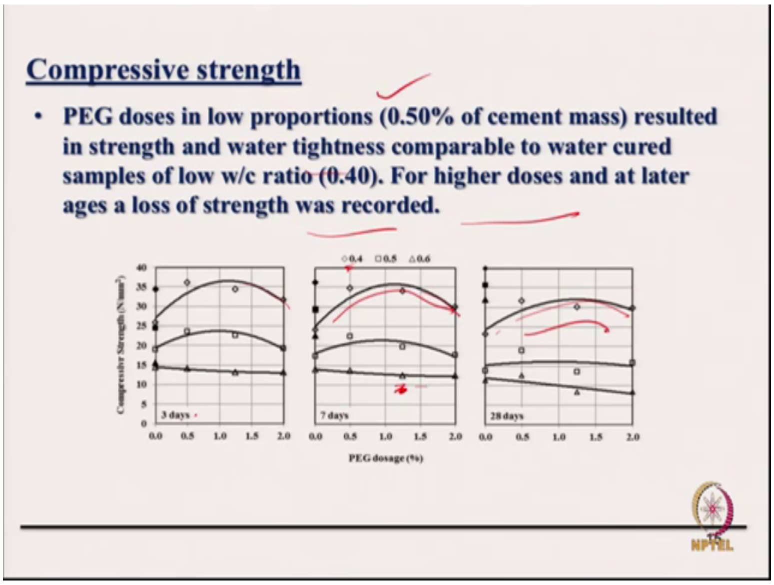

Compressive strength, compressive strength of mortar specimen increase with SAP dosage, SAP action becomes eminent after 3 days of curing age. Higher SAP doses with finer sizes is expected to perform better. Ok, that is alright, so compressive strength there is no effect really, that is what we are saying. And PEG doses in low proportions of cement resulted in strength and water tightness comparable to water cured samples. For higher doses at later ages a loss of strength is recorded, so you have to be careful, so you have to know that there can be PEG can cause loss of strength as well. In other words one has to verify these materials before using them. So, you need an engineered material design system wherein the laboratory you will first test them and then make sure that the things are all right, then only we will do it.

So you can see that strength increases, there is a reduction. Strength, different water cement ratio we are talking about, strength increases and there is reduction at of course, this is you know 7 days, this is 3 days. So, this is PEG doses different water cement ratio, this is high water cement ratio. In high water cement ratio there is no problem. In the low water cement ratio in this, this reduction is observed. So there you can use them but after proper verification.

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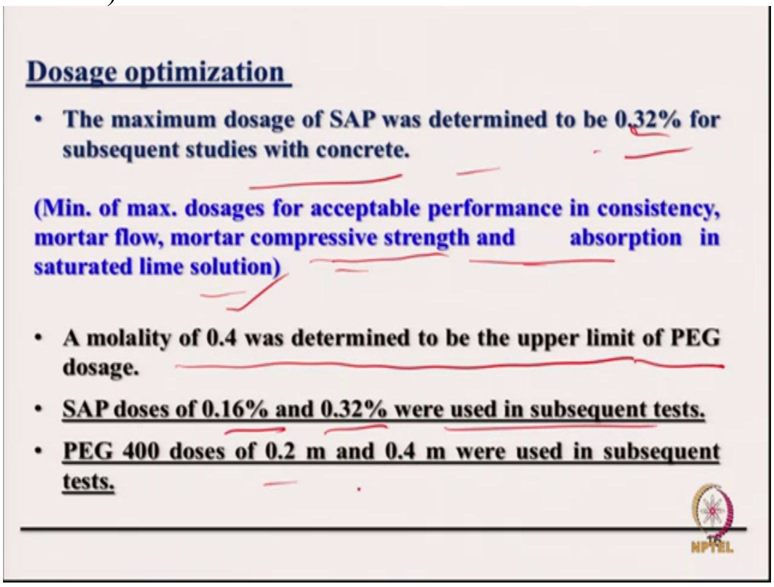

The maximum dosage of SAP of course could be of the order of 0.32 percent for subsequent you know, so you can optimize them and find out what is the best. Minimum and maximum dosages for acceptable performance in consistency, mortar et cetera, first you should find out. And molality of 0.4 was upper limit of PEG concentration, we are talking of SAP dosage of 0.16 are used, ok it is all right.

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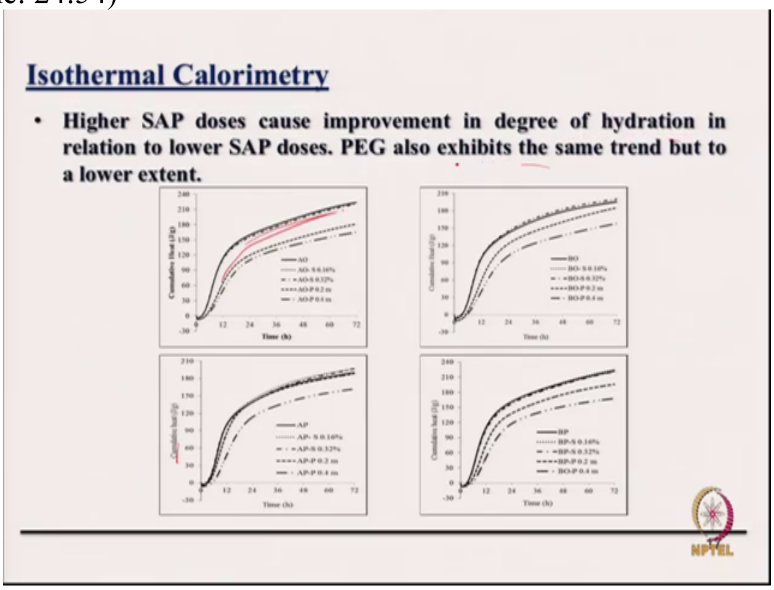

So some more results are available. If you look at calorimetry which we use to find out heat of hydration and all that, that would tell us, so you know the heat of hydration for various cases, so exhibit same trend but ok. It does cause improvement in degree of hydration in relation to water. So calorimetry gives you idea related to degree of hydration because heat release, so heat release rate if you see various cases it is showing, so there trend is similar and you know degree of hydration improves a little bit with this kind of activity.

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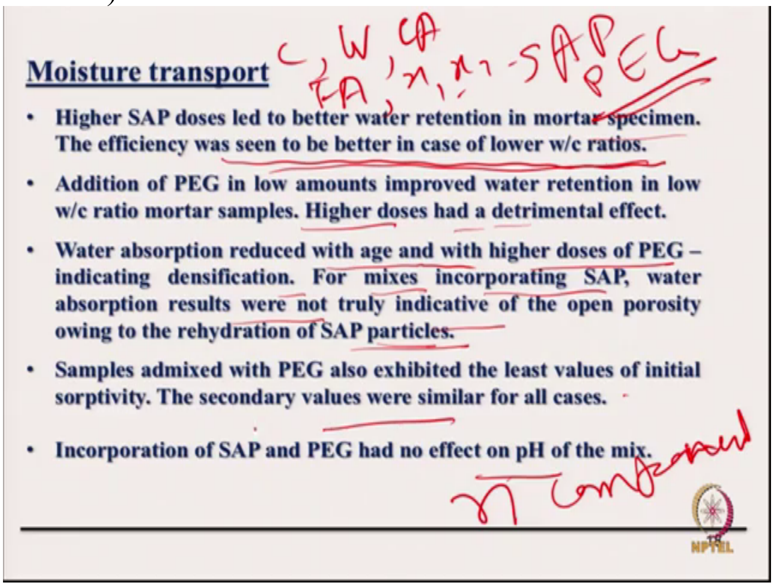

Similarly moisture transport if you look at it, because durability issues are there, so higher SAP doses lead to better water retention you know in mortar specimen. The efficiency is better, ok in lower water cement ratios. PEG in low amount improves water retention in low water cement ratio. High dosage that means the same thing, strength we have seen, so dosage has to be optimized. Water absorption reduced with age and with higher doses of PEG indicating densification. For mixes incorporating SAP, water absorption results were not truly indicative of open porosity or into the rehydration et cetera. So the point that for your class what I would mention is I suggest is essentially that these materials are available, superabsorbent polymers or PEGs which are curing admixtures.

You got to use them as we see the dosage has to be optimized or properties has to be checked before using because this has to come to such a level that you can use it though, so it has to be an engineered concrete. That is why I was talking about and component of concrete not four, n component, so cement water, coarse aggregate, fine aggregate you know x1 x2 et cetera, different varieties of admixtures are possible and you have to design the system for sustainability and for your performance that you require. Ok, pitch of the mix do not change because that has something to do with durability, this initial absorption et cetera, ok so durability some durability properties it shows, proper improvement.

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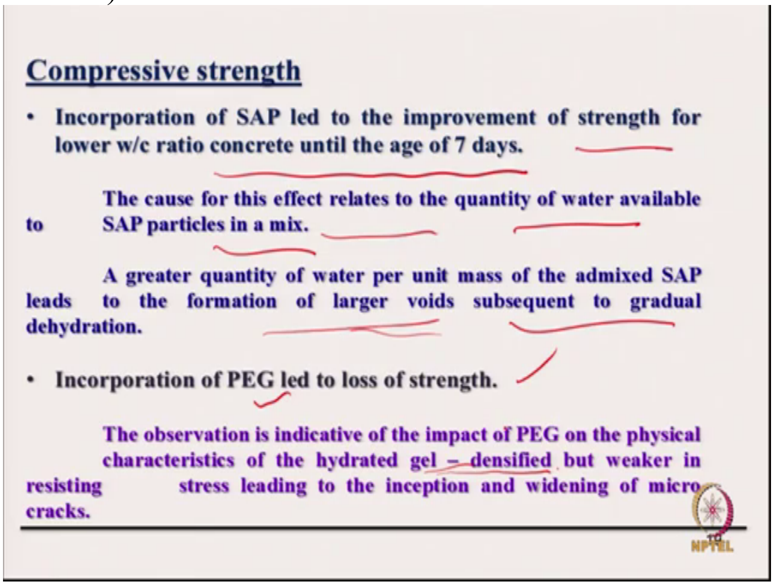

Improvement in strength for lower water cement ratio is 7 days beyond that it reduces, the cause for this effect relates to quality of quantity of water available in SAP particles, means a greater quantity of water per unit mass of the admixed SAP leads to the formation of larger voids, ok, there is a details. But I think I have made my point already that incorporation, loss of strength in the long run PEG you know, the structures one can look into the microstructures and things like that.

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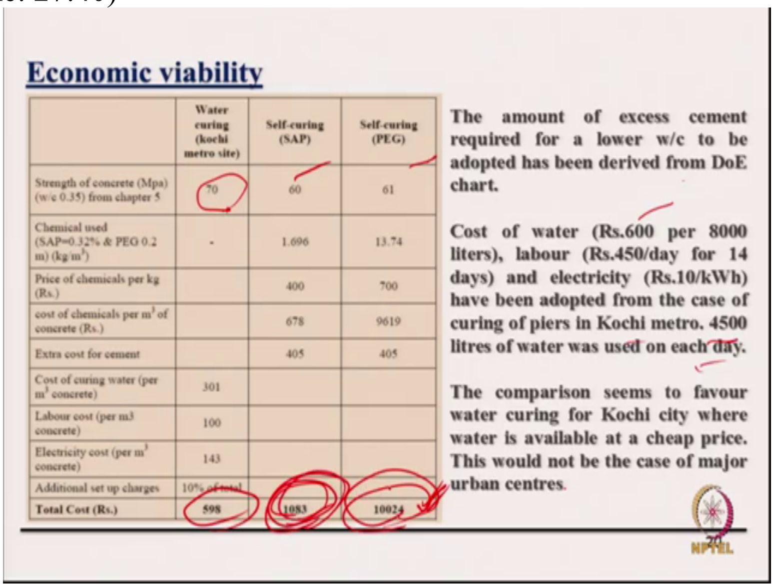

So there is a possibility of using all this. If you see the economics part of it then one can find out the cost because this itself has got some amount of cost implication, total cost of concrete one can calculate out for the similar strength of concrete, so if you see that you will find out you have taken a practical concrete used in Kochi metro. There is an self-curing there is a cost increases significantly. So it was per meter total cost per meter cube, there is a self-curing, there is a cost increase is very much there. So, amount of excess cement required, lower water cement ratio if you want to get the same strength, so the cost of, cement will also increase.

So you have to see what is more important here, this curing admixtures if you are using the cost particular case that we looked into for Kochi metro let us say because I want to get the same strength, lower water cement ratio strength that is reduced, so I might use more cement and the cost increases with this kind of material for the same strength the cost increases. So you have to see the economics part of it if you are using this but these options remain and possibly more research would show that possibly economically one can use these admixtures.

There are other advantages where water is absolutely scarce. One might try to use them where water scarcity is not so much rather the problem is you know the cost of cement will increase if you want to get high strength system. In low strength system still you can use this.

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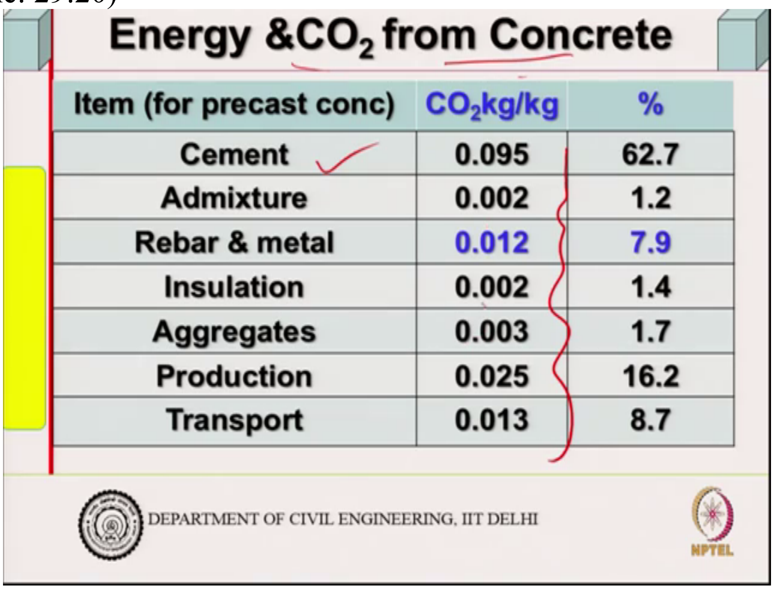
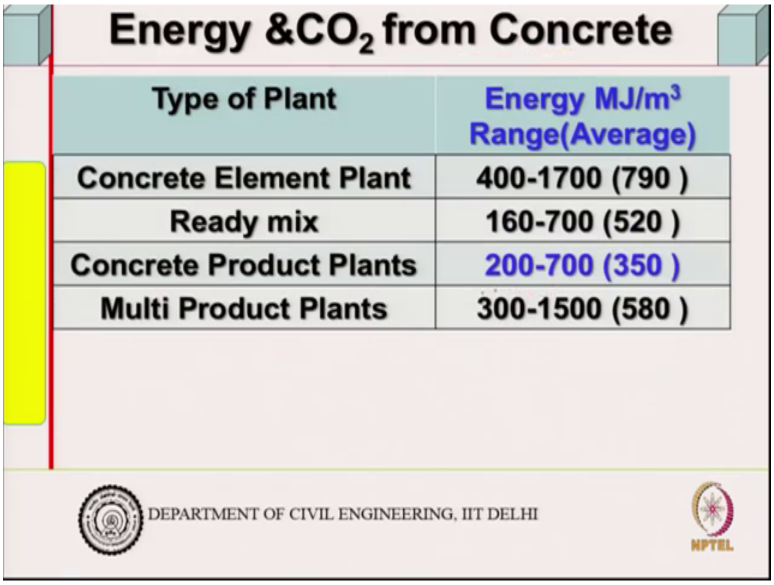


Item (for precast conc)	CO_2kg/kg	%
Cement	0.095	62.7
Admixture	0.002	1.2
Rebar & metal	0.012	7.9
Insulation	0.002	1.4
Aggregates	0.003	1.7
Production	0.025	16.2
Transport	0.013	8.7



So, if you see the different construction of precast concrete, energy and carbon dioxide from the concrete system, I think we will look into this in the next class. River and metal just quantity of carbon dioxide that is what comes through. So from production process we will look into this in the next class. We will look into this. So this, at this stage I think we will stop here and if you have any questions I would like to answer them.