Hydration, Porosity and Strength of Cementitious Materials

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Lecture – 11
Portland Cement Based Paste System – I

Hi, good morning to one and all, I am K V Harish, assistant professor, Department of Civil Engineering, IIT Kanpur; you are watching MOOC lecture course on hydration porosity and strength of cementitious material.

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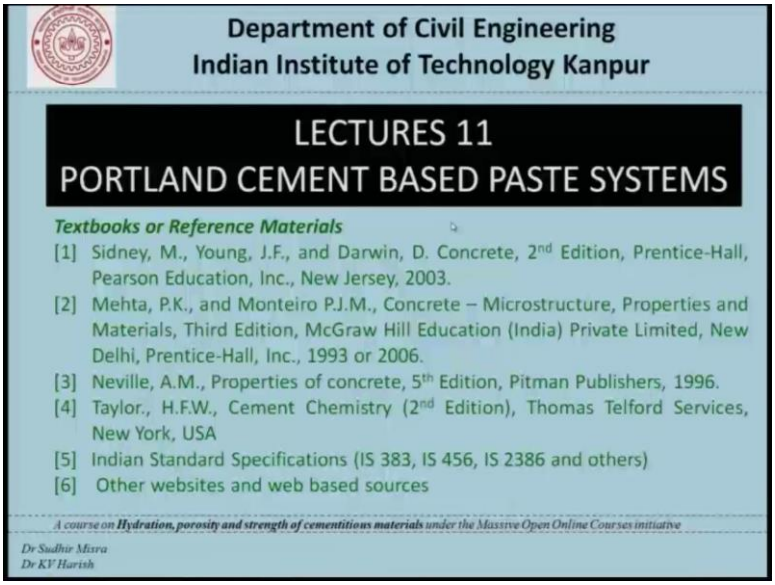

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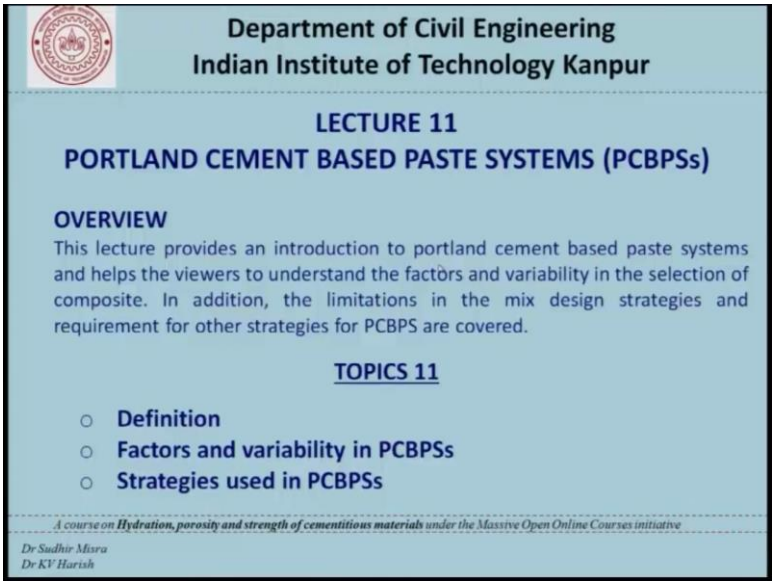

Now, we will be saying lecture 11; Portland cement based paste systems, the text books and reference materials are shown the topics that will be covered in this lecture is definition of Portland cement based paste systems some factors and variability that you have in Portland cement based paste system and also strategies that you use in Portland cement based paste system. And an overview for this lecture is as follows this lecture provides an introduction to Portland cement based paste systems and remember that the terminology Portland cement based paste system is something that we are introducing in this lecture and you generally will not find this terminology elsewhere in any text book or other places.

We will at a later stage discuss about the importance of this terminology. So, this lecture provides an introduction the Portland cement based paste systems and helps the viewers to understand the factors and variability in the selection of a particular composite for application. In addition the limitations in the mix design strategies and requirements for other strategies for Portland cement based paste system is also covered from this lecture onwards Portland cement based paste system will be referred as PCBPS. So, on the viewers may make a note of that.

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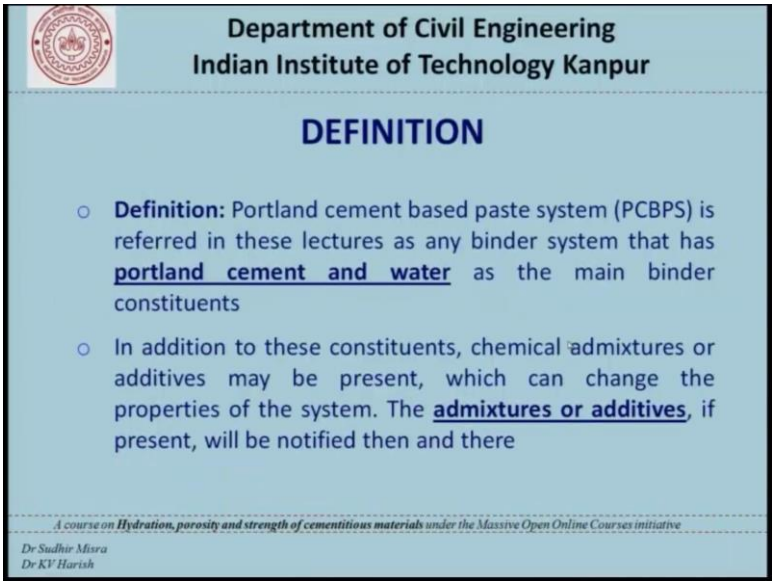

So, definition Portland cement based paste system we are referring in this lectures as any binder system that contains Portland cement and water as the main binder constituent that does not mean that the binder constituent should only have Portland cement and water it may have some admixtures or additives or chemical admixtures. So, the presence of these admixtures additives can actually modify the Portland cement or Portland cement paste.

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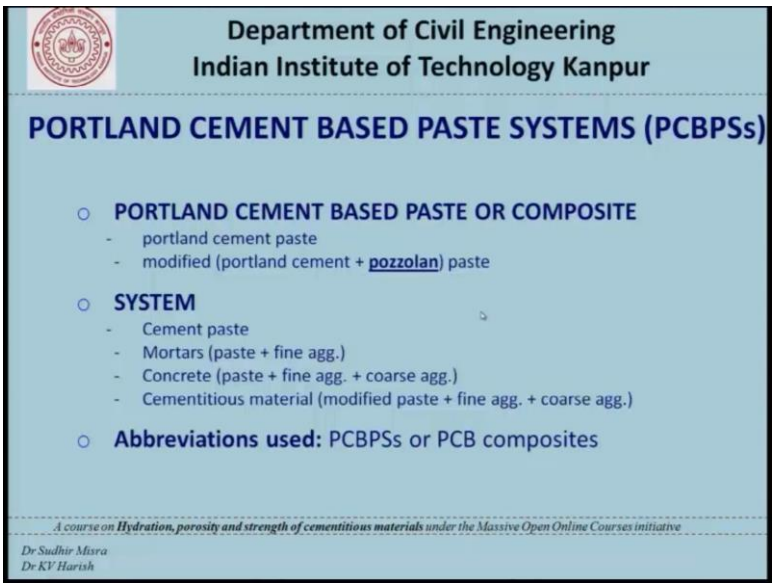

So, we are introducing this broad terminology for easier understanding of the audience. So, in PCBPS what we have is the terminology is divided into 2 parts one is Portland cement based paste or composite in that you have Portland cement paste you also have a modified port Portland cement paste where the influence of pozzolan can actually change the properties of the paste information about pozzolans mineral admixtures and other things will be covered from lecture 21 to lecture 30.

Now the word system is introduced primarily to say that you also have a cement paste system you also may have mortar system you may also have concrete system you also may have cementitious material system and what you find in all these four systems is that the cement paste is basically common for mortar and concrete and the additional entity is fine aggregates in the case of mortars and fine aggregates and coarse aggregates in the case of concrete with regard to cementitious material because of the presence of pozzolans or mineral admixtures the cement paste gets modified and in addition to that you may also have fine aggregates and coarse aggregates.

So, the abbreviations typically uses in these lectures are PCBPS or PCB composites both refer to the more or less same meaning.

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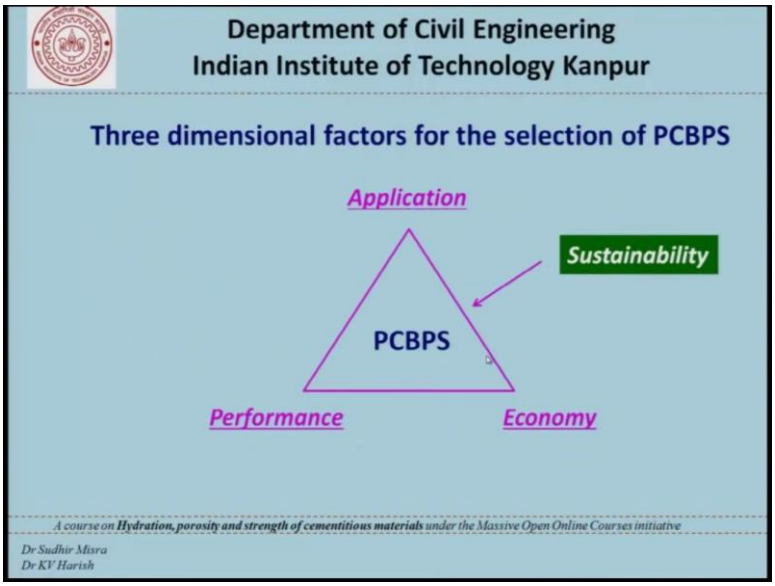

Now, the 3 dimensional factors that you have for the selection of Portland cement based paste system is application based factors performance based factors and economy based factors these dimensional factors primarily stand as critically important factors. And in

addition to this 3 factors you may also have a fourth factor called as sustainability which provides a completely new dimension to these 3 factors currently in this lecture we will not discuss about sustainability once we go to mineral admixtures or pozzolans which is between lectures 21 to 30 we will see about sustainability substantially.

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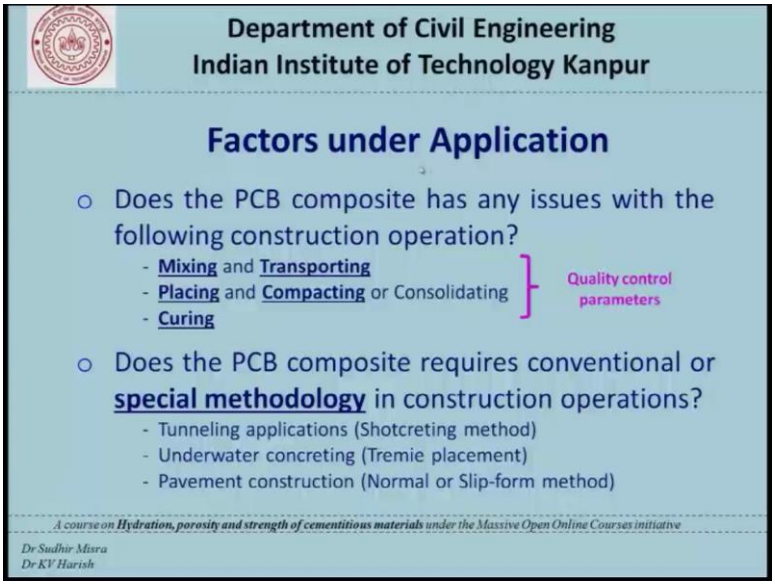

Now, let us first see the application factors under application what we generally see is that do we have any construction based factors from application stand point. So, in such a case we have to question ourselves many times engineers question themselves to see whether the Portland cement based composite has any issues with respect to the construction operations that are conventionally performed at the site some of them or mixing and transporting placing and compacting the other word is also called as consolidating and curing. So, do you have affect the construction operation and these are broadly under the topic quality control parameters and in addition to these factors the second question that we need to think when it comes to application is thus the Portland cement based composite requires conventional methodology or special methodology in construction operations.

So, for example, if you take a say tunneling operation where you want to concrete portion of the lining of the walls in special operations are required like short creating. So, where as if you take a underwater concreting it totally use a different special methodology called tremie placement or sometimes even we can use there may be

multiple special methodologies. So, the introduction of each of these methodology will have their own factors and that will come under this application factor and likewise if you take a say a pavement construction we have choices of either going ahead with the normal construction operations or we may have a sophisticated methodologies like slip form method. So, the choice of the method that is used for a particular application and can be a big factor and there may be other factors in the methodology which can play a significant role.

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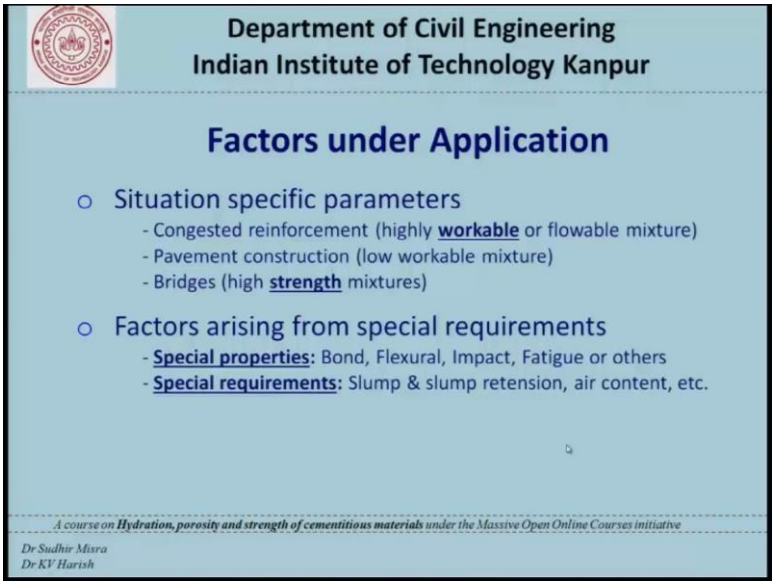

Now, the third one we can also have situation specific parameters for example, assume that a concreting is done at the site and if you have in a particular location congested reinforcement then in that case we prefer to have a highly workable or flowable mixture. So, that it can completely fill the forms and reinforcements or completely filled with concrete in the other case we could also have a payment construction as we have seen in the previous point and for which you do not need a high workable mixture in such cases we can handle with low workability if you take bridges for certain types of bridges we may have to use high strength mixtures. So, what basically happens is the situations are different for these 3 cases.

So, likewise the properties also are different many times factors arise because of situation specific conditions likewise if you take the fourth point factors arising from special requirements. For example, for certain applications we need special properties

such as high bond strength high flexural strength high impact strength high fatigue strength or other strengths similarly there may be special requirements like high slump high slump retention primarily high slump retention is required if the transportation of concrete is going to take place after a particularly slump retention is required when concrete has to be transported over longer distances before placement likewise you may have a freezing and thawing environment for which the special requirement is that you need additional air content in the mixture.

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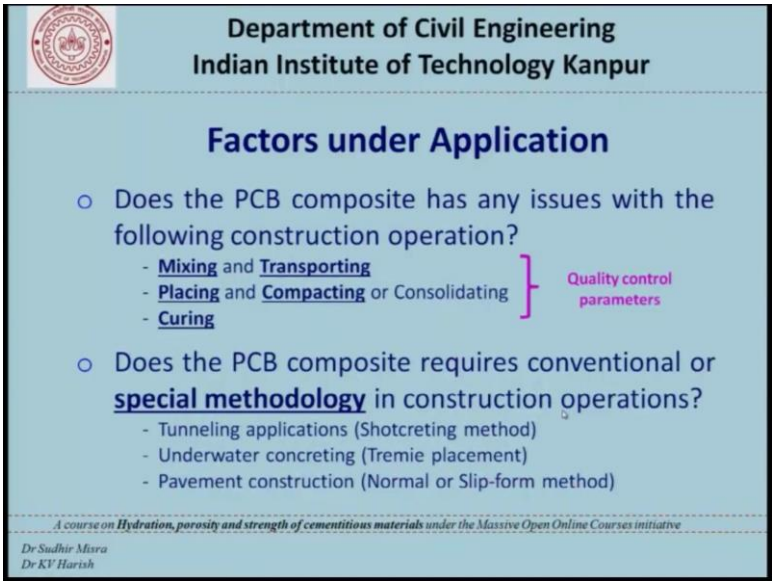

So, what we have seen here is that under application depending upon the construction operation or the special methodology used or situation specific or special requirements the factors keeps on changing and for different application we have different set of factors that come into picture and this is primarily important when you go for the selection of a particular Portland cement based paste systems.

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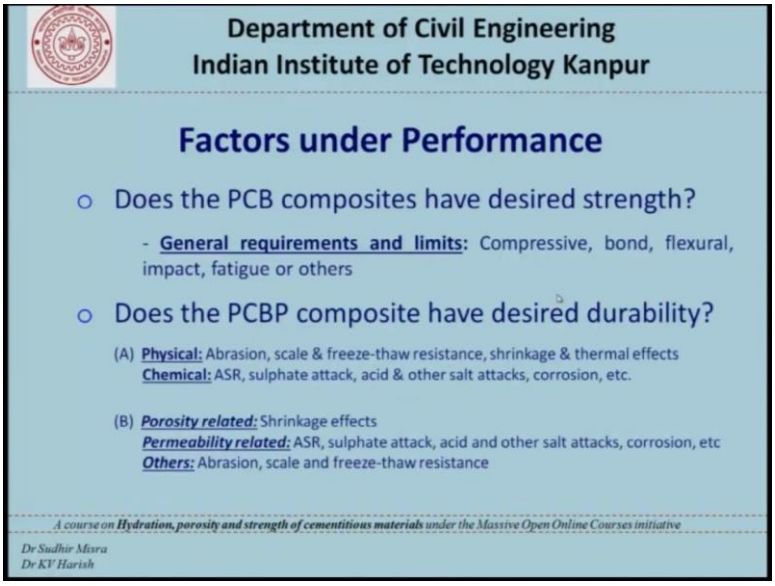

Similarly, when you see the second dimension which is performance the questions that are generally asked are as follows does the Portland cement based composite have desired strength remember here these are not special requirements these are general requirements and what are the general limits that are provided by the standards and when we say desired strength it does not have to naturally be compressive strength it could be bond strength flexural strength impact fatigue or others, but remember that in this case we are talking about general requirements we are not talking about special requirement as in the case that we have seen previously. So, the normal limits that you have for compressive bond flexural impact fatigue or others should also be known as a performance factor.

Now, coming on to the second one which is thus the Portland cement based composite have desired durability now durability is again a very broad terminology and there are different causes of deterioration that happen in Portland cement based paste systems some could be physical some could be chemical and some examples are provided here. So, the durability factors can be divided into 2 parts one is a physical the other one is a chemical physical you may have abrasion resistance you may want your concrete to be resistant to abrasion you may want your concrete to resist scaling actions and freeze thaw actions at the same time you may also want concrete to resist shrinkage or thermal effects and all these things come under physical. Now moving on to chemical you may

either have alkali silica reaction distress sulphate attack acid and other salt attacks corrosion, etcetera.

So, you have lot many factors that come under durability and depending upon the environmental condition and the situation we may have to choose one of these factors remember that in some cases 2 or 3 factors could also come together the same properties that we have seen under durability can also be grouped in a different way for example, you could have porosity related issues where shrinkage effects comes under this category you may also have ASR sulphate attack acid and salt attacks and corrosion coming under permeability related parameters and you may also have others where abrasions scale and freeze thaw resistance can be grouped.

Remember that porosity is also connected to permeability in a particular sense at the connection of porosity and permeability is not clear at this point of time, but remember that in cases where porosity and permeability or related then these factors under permeability will also be factors under porosity and vice versa.

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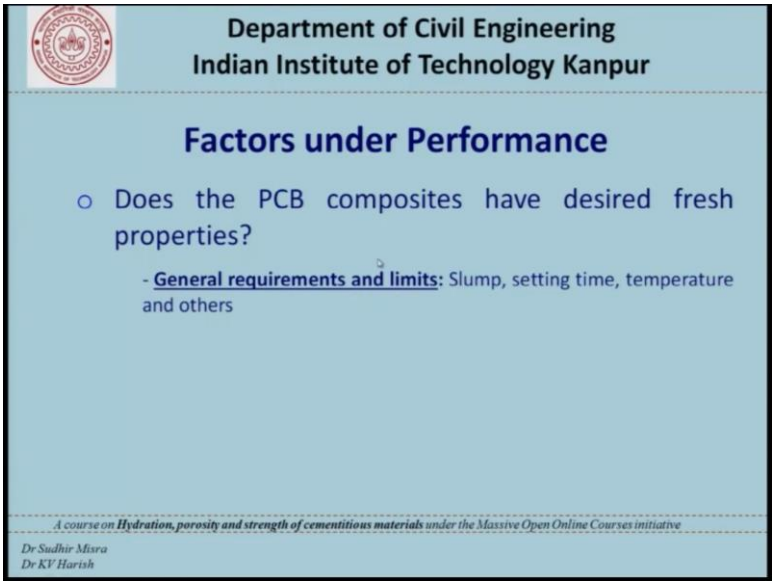

So, the third question which comes to mind is does the Portland cement based composite have desired fresh properties and again when we talk about fresh properties, we are talking about general requirements and limits. So, from an engineer standpoint it is extremely important to understand what is the conventional slump levels that are required for a particular application and what is the setting time limits? The initial setting

time as well as final setting time limits and the conventional range of temperatures and several others, so the performance is largely seen under this head from the angle of general requirements and limits.

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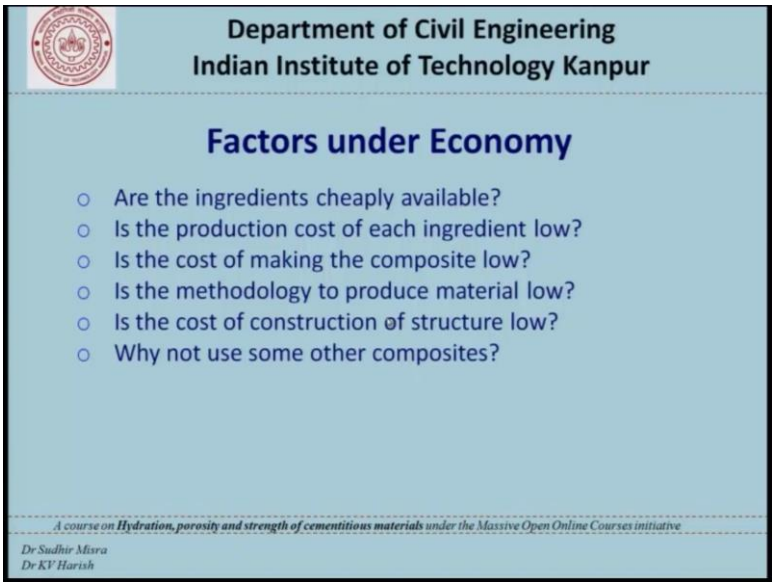

Coming on to the third dimension which is factors under economy the questions generally asked is are the ingredients used for the composite cheaply available the second one is the production cost of each ingredient low is a cost of making the composite low is a methodology to produce material low sorry is the cost of methodology to produce material low is the cost of construction of the structure low why not use some other composites. So, these questions have to be properly addressed under the dimension economy in order to make sure that a particular composite can be used for application.

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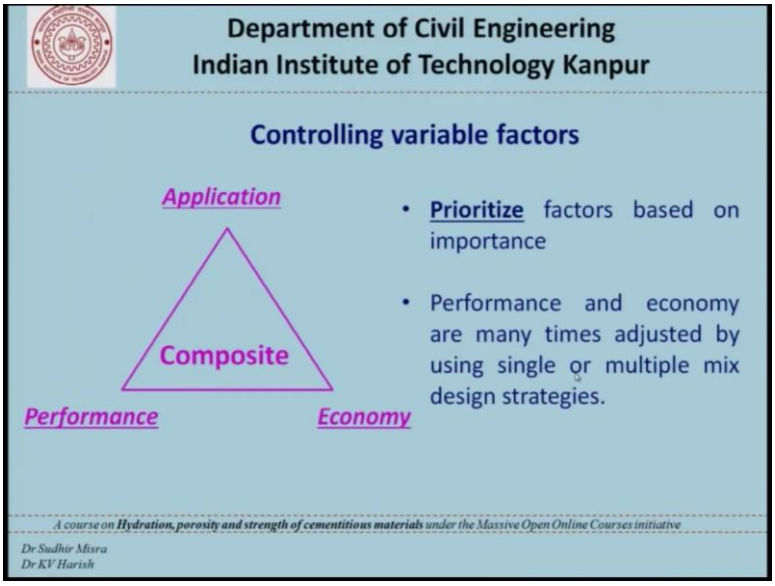

So, in the last a few slides we have seen that you have several factors under the 3 dimensions application performance and economy and how do you control these factors the first thing that is important for controlling is that we need to first a prioritize the factors based on importance and remember the importance is again a very broader terminology because for each application the performance differs as I; as we have already seen there are general requirements as well as special requirements.

So, prioritizing the factors come first performance and economy are many times adjusted by using single or multiple mix design strategies this is very important I repeated performance and economy or many time suggested by single or multiple mix design strategies and we have already seen some of the mix design strategies to control workability durability strength and economy already under the lecture; mix design strategies.

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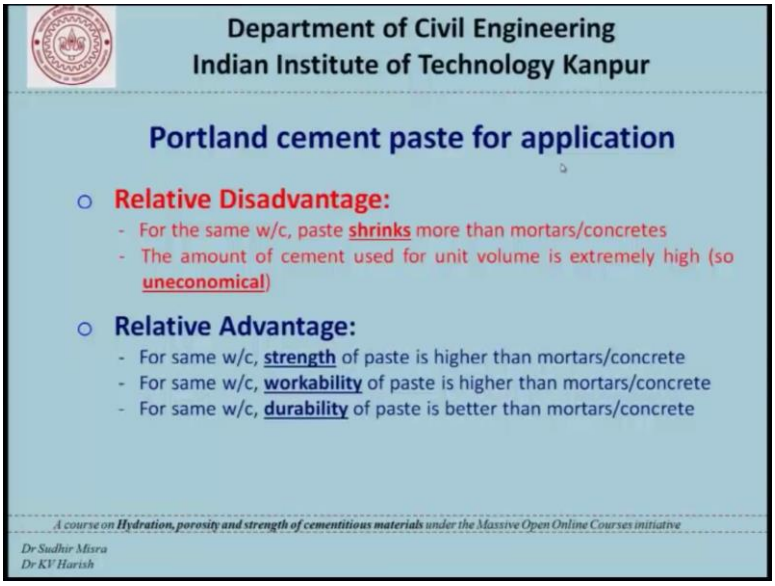

Now, when we think of using Portland cement paste for application what we need to question our self is do we have advantages or do we have disadvantages and we usually compare the cement paste with mortars or concrete.

So, when we do such comparison the relative disadvantage and the word relative is important for the simple reason that we are comparing the application of paste with that of mortars and concrete only. So, the relative disadvantage that you have in paste is that for the same water to cement ratio the paste is shrinks more than mortars or concrete the amount of cement that is used for unit volume is extremely high and that makes the paste uneconomical for most application. So, these are the 2 main disadvantages that we have with cement paste now do we have advantages over mortars or concrete answer is yes we have advantages for the same water to cement ratio the strength of paste is higher than mortars or concrete for the same water to cement ratio workability of paste is higher than mortars or concrete.

For the same order to cement ratio durability of paste is better than mortars or concrete remember that strength workability durability are comes under performance factors and from the performance factors paste is very good for application, but in terms of economy factor it is; it has a huge disadvantage.

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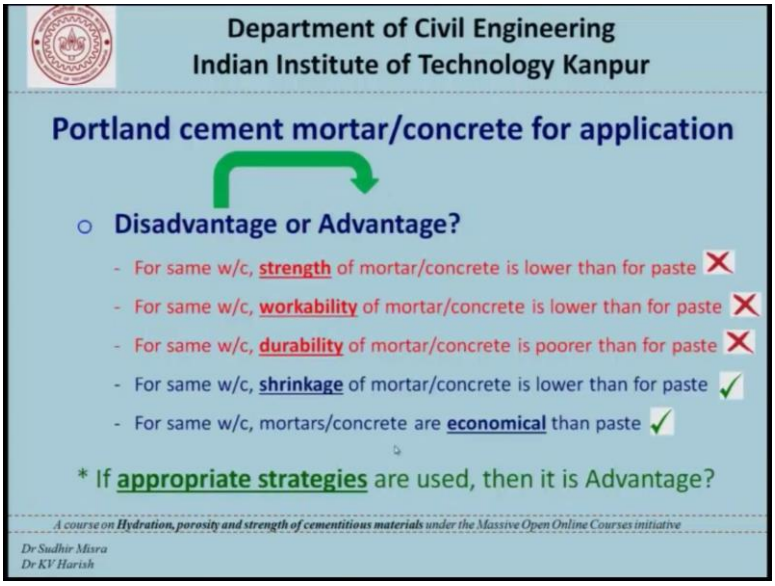

Now, let us move to Portland cement mortars or concrete when we are saying for application now the same slide if you see from the standpoint of mortars what we have is that for the same mortar to cement ratio strength of mortars or concrete is lower than paste and likewise for workability and likewise for durability. So, the negative that you have in mortars or concrete is primarily because of the use of fine aggregates and coarse aggregates in proper proportions.

So, and likewise if you see the advantages the shrinkage of mortar or concrete is substantially lower than paste and mortars and concrete are very economical compared to paste. So, you have 2 advantages and you have 3 disadvantages just because you have 3 disadvantages you cannot completely say that mortars or concrete have cannot be used primarily because we can use strategies the right strategies to convert the disadvantages to advantage. So, primarily this is done during the mix design stage and we have already seen the mix design strategies.

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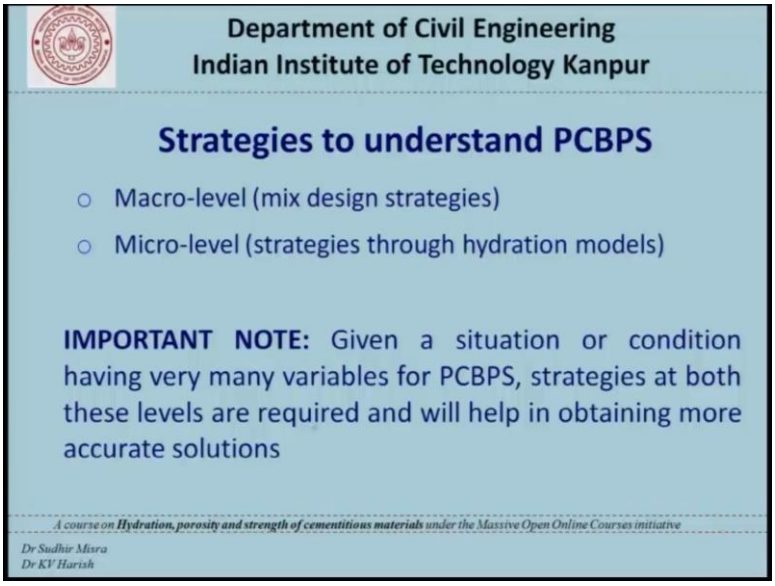

Now, what are the strategies that you have to understand Portland cement based paste systems we usually have 2 categories broadly classified one is the macro level strategies the other one is the micro level strategies in the macro level strategies we have the mix design strategies for each of the performance characteristics and in the micro level strategy we have to study based on hydration models.

Now, the question arises why do we need a micro level strategy when already macro level exist now for that an important note is provided given a situation or condition which has very many variables for Portland cement based systems which we saw recently strategies at both levels are required and will help in obtaining more accurate solutions now let us see what is what are the limitations of mix design strategies and then see the advantages of micro level or strategies through hydration models.

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Now, the limitation of the mix design strategies is that they help in understanding the workability strength and durability or other performance properties of concrete arbitrarily which means some random bases is used in order to arrive at these strategies.

In specific if you see durability as I have already mentioned is extremely diverge area since each of the durability distress that we are actually saw in the previous slides has a definite mechanism associated and this mechanism could be associated with the binder or with the filler or with filler and binder. So, the understanding of these mechanisms require knowledge about the composite at the micro level and this micro level knowledge is not provided or not considered in the mix design strategies which we saw in the previous lectures.

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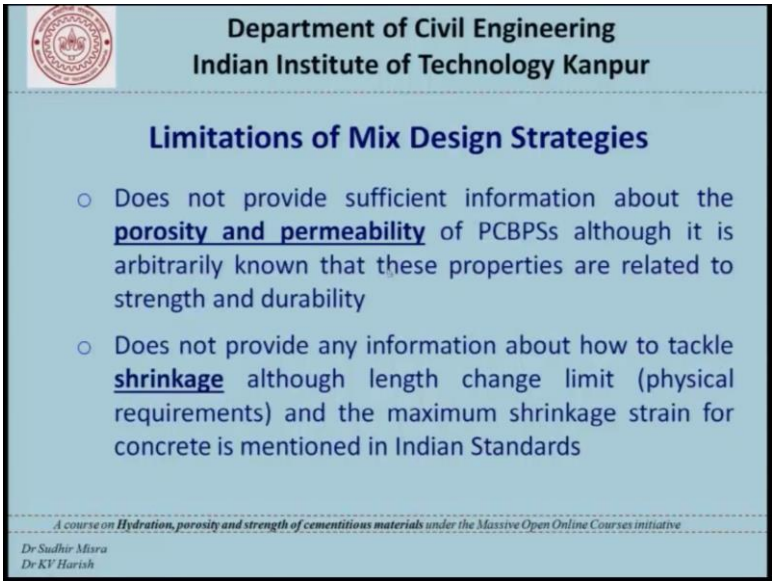

At the other limitation is that mix design strategies does not provide sufficient information about the porosity and permeability of Portland cement based paste systems although it is arbitrary known that these properties are related to strength and durability.

So, in the mix design strategies what we have seen basically is how to adjust the proportions of ingredients primarily water cement fine aggregate coarse aggregate and others which one to increase which one to decrease and all those things, but; however, the porosity and permeability information is completely unknown from those strategies the next one is mix design strategies does not provide any information about how to tackle shrinkage remember shrinkage is a very important property which could either come under durability heading or it could come under long term properties. And already we have seen in previous lectures that length change limits and maximum shrinkage strain for concrete is mentioned in the Indian standards.

So, if you go to the physical requirements for cement you see that there is some length change value that is provided from the standpoint of shrinkage likewise maximum shrinkage strain for concrete is also mentioned in IS 4562 thousand, its value is approximately 0.0003. So, when these limits are actually provided we do not know the basis on which those limits are provided and these are not clearly addressed in the mix design strategies this is primarily because shrinkage is a property that is related to the porosity of the Portland cement based systems and hence since porosity and permeability

are not proper properly dealt in mix design strategies information about shrinkage is currently not present.

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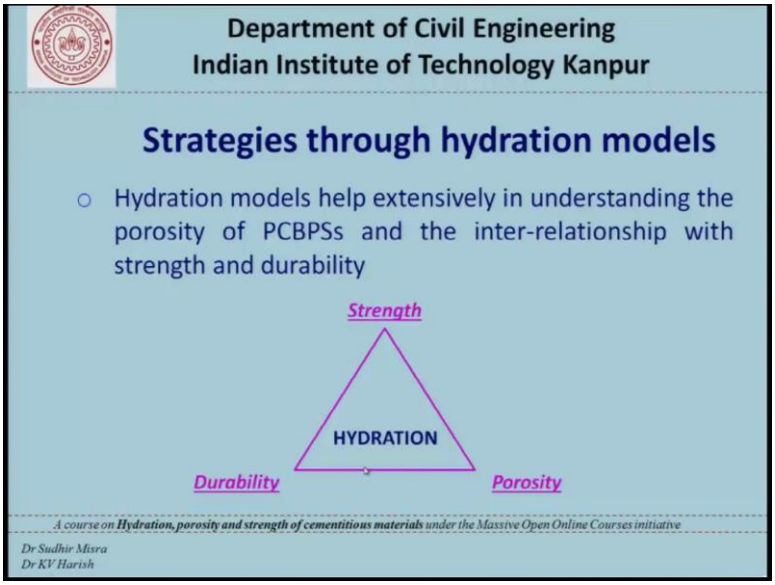

So, now coming onto the micro level strategies through hydration models the hydration models help extensively in understanding the porosity of Portland cement based paste systems which you cannot find in the mix design strategies and they also try to interrelate the development of compounds with the strength and durability remember strength and durability is generally viewed from a macro level and porosity is generally viewed from the micro level. And hence if you could it in a form of a triangular representation taking strength on one side and durability on the other side the porosity which is a micro level property the correlation between strength and porosity should be understood and likewise a correlation between porosity and durability should also be understood and these can be understood only through the knowledge on cement hydration.

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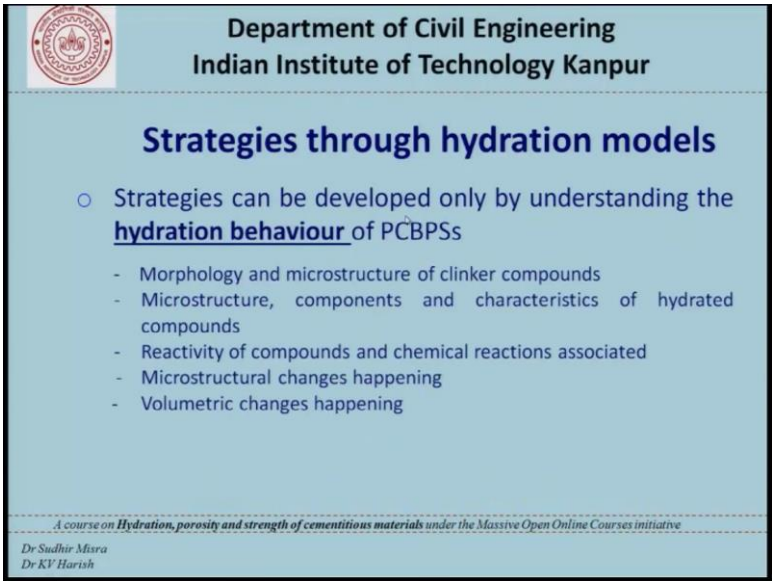

Strategies through hydration models can be developed only by understanding the hydration behavior of Portland cement based paste systems and in order to understand the hydration behavior you need to understand the following things morphology and microstructure of clinker compounds microstructure components and characteristics of hydrated compounds. Remember morphology and microstructure is for the unhydrated compounds and the microstructure components and characteristics is for the hydrated compounds and reactivity of compounds and chemical reactions associated micro structural changes that are happening inside the system and volumetric changes happening inside the system.

So, if you understand all these things then you can understand the hydration behavior you can understand the porosity and the interrelationship of porosity and strength and porosity and durability.

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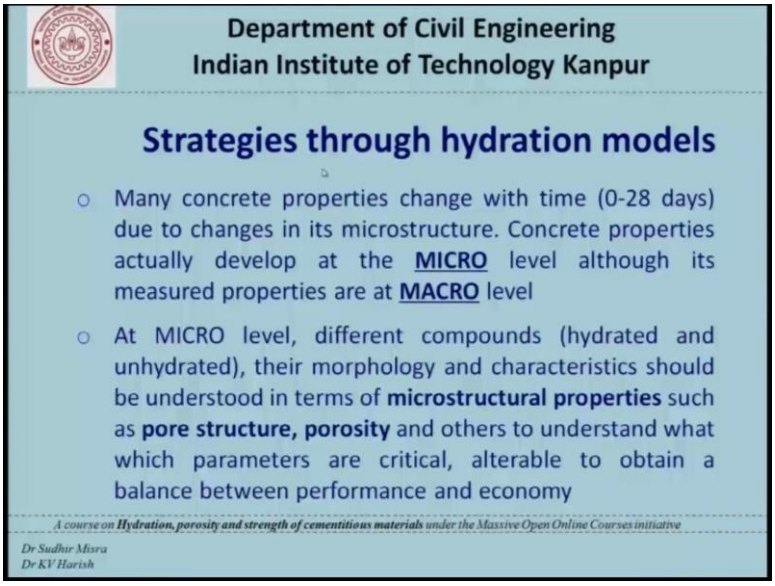

Under strategies through hydration models we can also find that many concrete properties change with time that is 0 to 28 days due to changes in its microstructure and concrete properties actually develop at the micro level although the measured properties are at the macro level at micro level different compounds both hydrated and un hydrated their morphology and characteristics should be understood in terms of micro structural properties such as porosity pore structure and others to understand which parameter is critical and which is not critical and which is alterable to obtain a balance between performance and economy.

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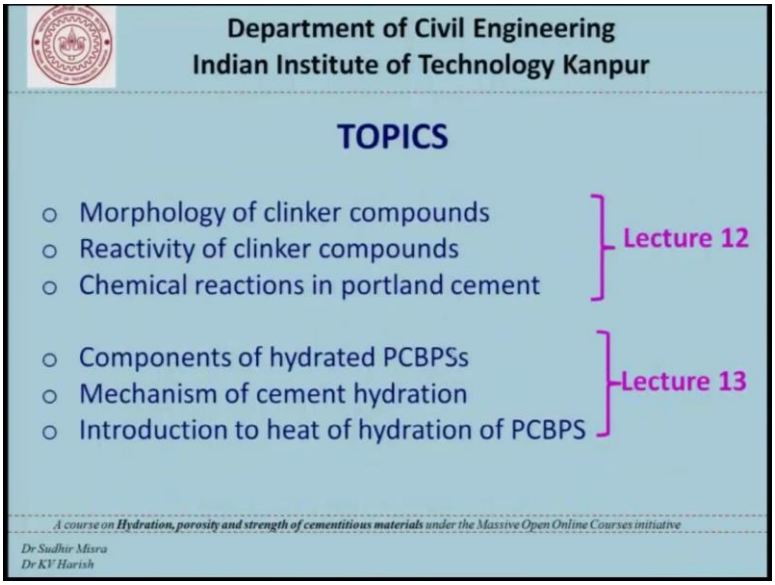

So, what we have seen in the previous lectures from say lecture 1 to lecture 3 done by Professor Sudhir Mishra is that you seen that concrete is a very versatile material with popular material has huge applications and we have also seen the importance of workability strength and durability and he has also covered some of the important test methods that that is conventional used for concrete and also some typical values or limits that are provided for each and for each property. And in lectures four to ten we have seen introduction about cement primarily the production and properties of cement aggregates again production and properties of aggregates we have also seen mix design strategies how to use Indian standard method of mix design; how to mix design, how to get a proper proportion based on some of the basic data provided for an engineer and also we have seen some chemical admixtures which can be added along with the concrete ingredients if a particular property like workability or air content is not achieved.

So, having covered lecture one to ten which actually focuses primarily on concrete lecture 11 to 20, primarily focuses on the hydration aspects of Portland cement based paste systems and the topics that you will see in this week are as follows. So, morphology of clinker compounds reactivity of clinker compounds chemical reactions in Portland cement all you will see under lecture 12 and components of hydrated Portland cement based system mechanism of cement hydration introduction to heat of hydration of Portland cement based system in lecture 13.

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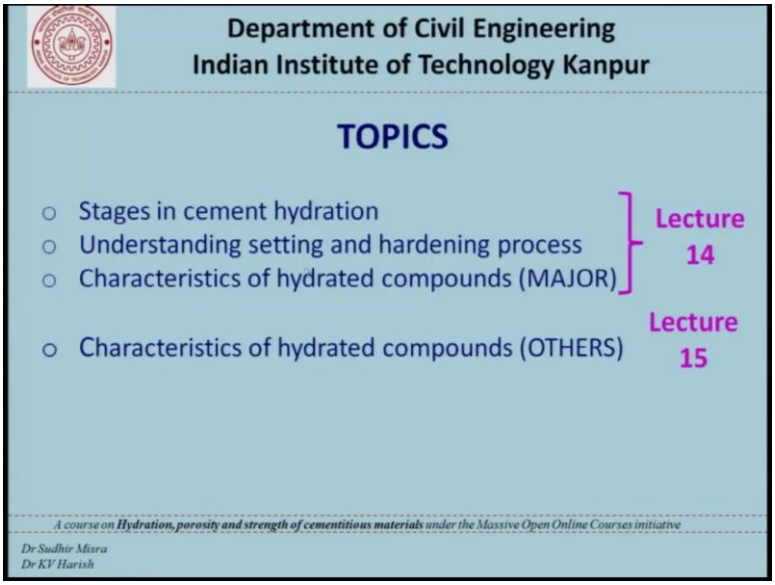

Stages and cement hydration understanding set setting and hardening process from the perspective of cement hydration characteristic of hydrated compounds and primarily we will see the major compounds that we will see in lecture 14 and characteristic of hydrated compounds not the major one, but others that are available that we see in lecture 15. So, this week we will see and with this lecture gets over.

Thank you.