Advanced Topics in the Science and Technology of Concrete
Experiments on Durability Index

A warm welcome to all the participants to this interactive lab session, I am Yuvraj Phd research scholar working in BDCM division with Professor Manu Sandhanam. Today we are going to look at some of the durability tests which are specified commonly these days in performance specification so in addition to compressive strength in concrete specification these days you will find some additional durability parameters which are specified, some of this we will see how the experiments have to be done.

So first it will be a rapid chloride penetration test one of the most widely used and accepted test in construction industry though there is lot of criticism about the kind of quantitative parameter which we get from the test, the test is fairly reasonable in studying the qualitative assessment of different batches of concrete or setting a certain quality of concrete and monitoring the concrete in a construction project over a period of time.

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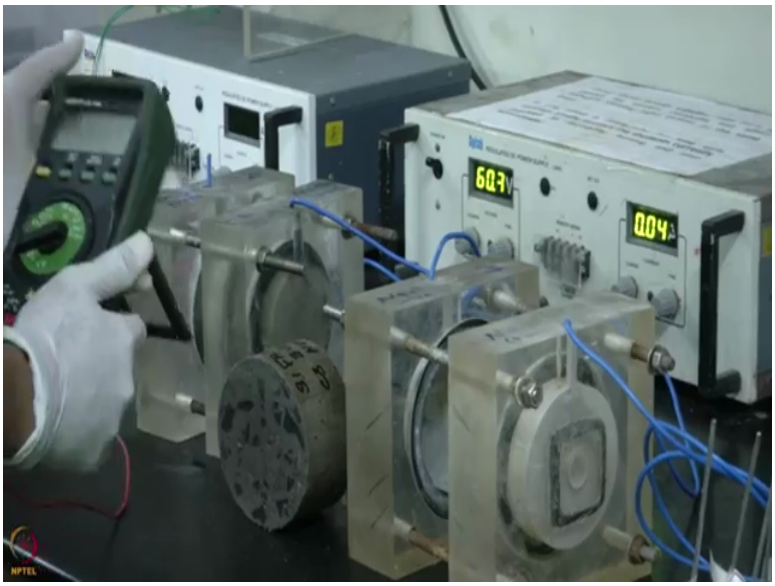

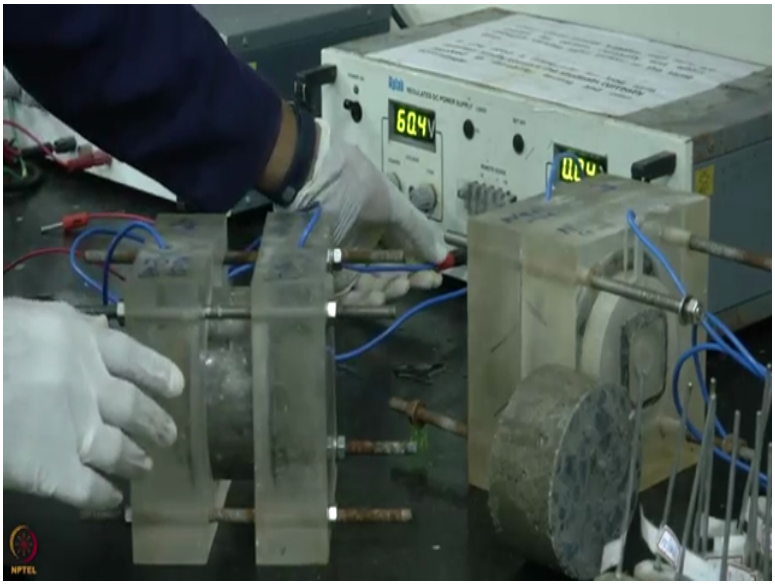

So the test is fairly simple so what we need to have is we have a standard cell where concrete will be placed so this is a typical cell so this cell is connected by a brash mesh to potential so we need a RCPT cell and potential supply and a multi meter to record the current response from the sample. So this is the typical sample which is used for the test so the sample is 100 mm cylinder and we have sliced it to about 50 mm, so the thickness of the sample is about 50 mm and the sample goes right in here so we need to place the sample and tighten the screws and fix it in case the cell, so this is one of the sample which is already kept in place, so the sample is placed air tight by the screws and then on both compartments we need to fill 3 percent NaCl and 0.3 molar NaOH and then we connect the cell to the potential so we connect the NaOH side to the positive and NaCl side to the negative of the potential.

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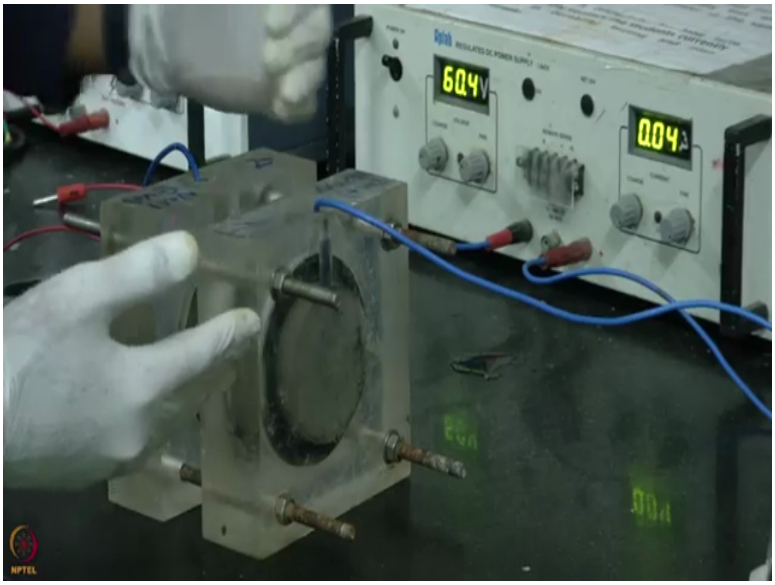

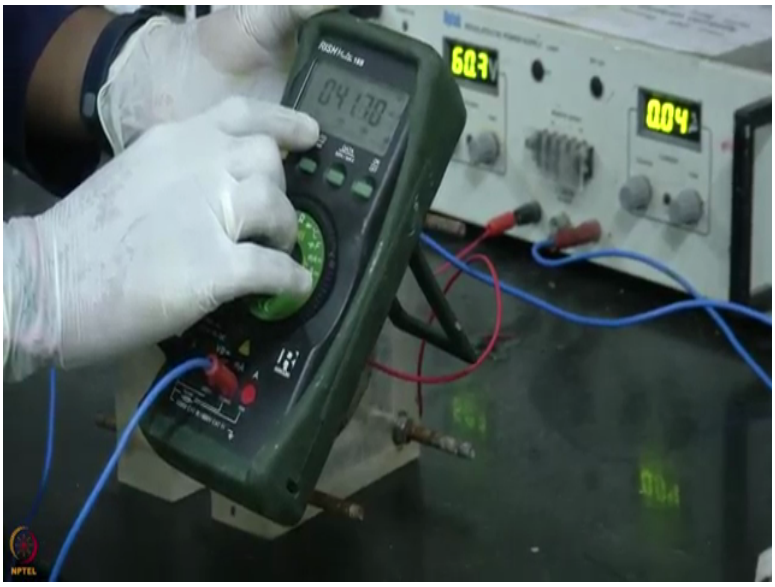

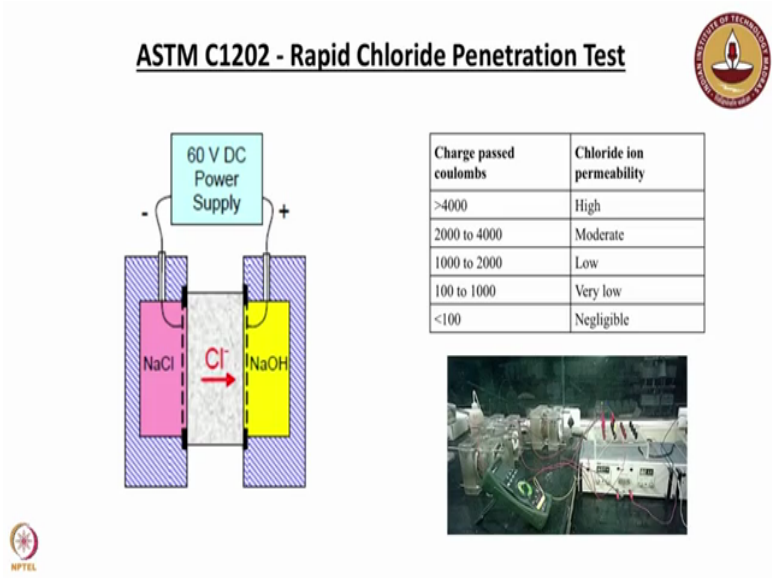

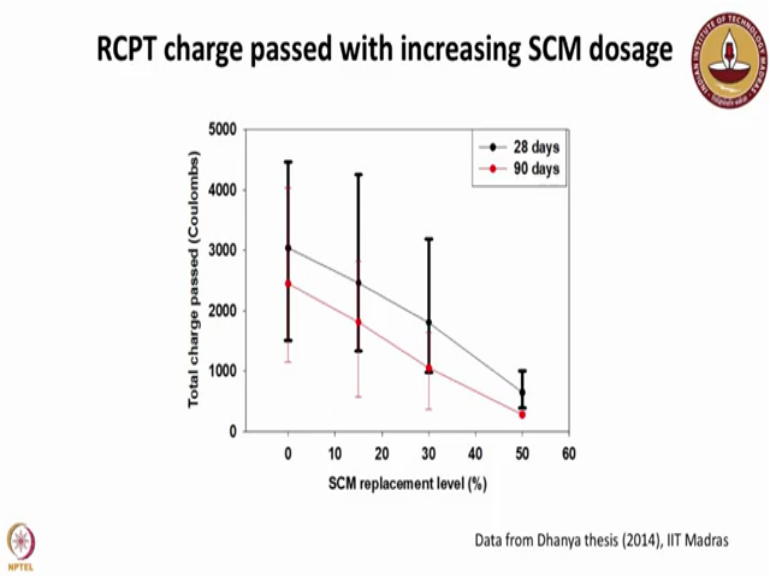

So the NaOH side of the compartment is connected to the positive and NaCl side is connected to the negative and the potential of about 60 volt is applied. So once the sample is connected you can see some amount of current which is showing up in the multi meter. So what essentially happen is once you apply a potential there is a positive potential applied opposite to the chloride ions, since chloride ions being negatively charged and the cations on both sides are Na plus, the negatively charged chloride ions tend to get pulled towards the concrete so it moves inside the concrete and try to reach the positive potential and what we measure is we start measuring the current so to measure the current we use a multi meter, the multi meter can be directly connected to the power supply so you just break the circuit and you will start seeing the readings in the current values in the multi meter. So the values are in milliamps.

So essentially we take this measurement at every 30 minutes for about 6 hours and take the cumulative of the current which will give a representation of the charge passed in the concrete, so the charge passed as different categories so ASTM C1202 has classified that a cumulative charge passed is less than 4000 the concrete is good, less than 2000 they say the concrete is good quality, less than 1000 it has very high resistance towards permeability and less than 100 cumulative charge passed the concrete is as very low permeability in the system though the measurement is purely electrical we have given a quantitative classification of the quality of concrete.

So this becomes reasonably useful in construction practise when you want to specify the quality of concrete which has to be used. So for instance this is very common in construction projects in infrastructure projects where they want to specify the quality of concrete to be

used on marine zone or 1.5 kilo meters from sea where there is very critical exposure you can set a very low RCPT value as a limiting factor for the acceptance of the concrete.

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So the sample preparation for this test involves you need to cut the sample into a 50 mm slice and then there is a process called lime saturation which is a 22 hour process, so initially you will place a sample in a vacuum desiccator and allow it to reach vacuum, then under vacuum we will fill a saturated lime solution, so saturated lime solution contains 3 grams of calcium hydro oxide in 1 litre of solution.

So we will immerse this under vacuum in calcium hydro oxide solution, then the vacuum will be kept on to remove any air bubbles inside the concrete for about 1 hour, post which the sample will be kept in a sub merged state inside the desiccator for period of about 18 hours. So this is a sample preparation involved in this experiment, this is whit the rapid chloride penetration test, the test can be widely accepted mainly because of the short time span which is required to this durability test, the entire test including sample preparation can be done within a span of 2 days, that actual test runs for about 6 hours, at the end of 6 hours you directly get a parameter which is representative of the quality of the concrete. So that is why the test is being very commonly used in the construction industry, thank you.

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So the next experiment which we are going to see is sorptivity test which is indicative of the water absorption rate in the sample. So depending on concrete structure is being put in place you need to do a different assessment, the first test which we saw on rapid chloride permeability is more dominant parameter when you are trying to measure a structure measure a parameter for a structure put in place of chloride exposure.

The other most common transport characteristics which happens in concrete is moisture, so the water gets into the concrete and reaches a surface of steel which is also necessary for corrosion to happen, so how do we assist the ingress of moisture into the concrete system? The simple fairly straight forward experiment called sorptivity test what we have is concrete specimen code from a cube, so this is a concrete cylindrical sample code from a 150 mm

cube, the diameter of the sample is about 70 mm, the thickness of the sample is about 30 millimetres, the sample is being conditioned in an oven at 50 degree celsius for nearly about 7 days.

What the conditioning does is it allows the moisture inside the sample to attain a relatively uniform level so the sample becomes dry with very low relative humidity inside the sample and then the sample is placed on a sleeve like this, so you will need two sleeves like a level (())(7:16) to place the sample, then the sample will be placed in order so it is necessary you place some marking on top of the sample to has an identification and then we immerse it in calcium hydro oxide solution like with the bottom 2 mm of the sample touching the calcium hydro oxide solution and then we measure the uptake of moisture by monitoring the mass change in the sample at regular time intervals.

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So now the sample is in position let me just place calcium hydro oxide solution let me just pore calcium hydro oxide solutions into the container so the solution is a saturated calcium hydro oxide, we have to use a saturated calcium hydro oxide solution because there are alkali and hydroxyl ion inside, so there are alkali and hydroxyl ion inside the concrete, if the concrete solution is not saturated there will be leaching of ion from the concrete to the exterior solution, to prevent that we need to use a solution which is saturated with calcium hydro oxide.

So once the sample is in place so the solution has to be filled such that 2 mm from the bottom of the sample the water level is from the 2 mm from the bottom of the sample, so once the sample is in contact with water we need to take the mass change of the sample at regular time intervals. So the mass has to be measured in this way like you take the sample wipe it on a

dry cloth make sure the surface excess moisture is being removed and then place the sample upside down so you do not bring the expose surface in contact with balance so you release any moisture which is up taken and note down the mass this has to be done fairly quickly and the sample has to be put in place back in the solution within a short span of time.

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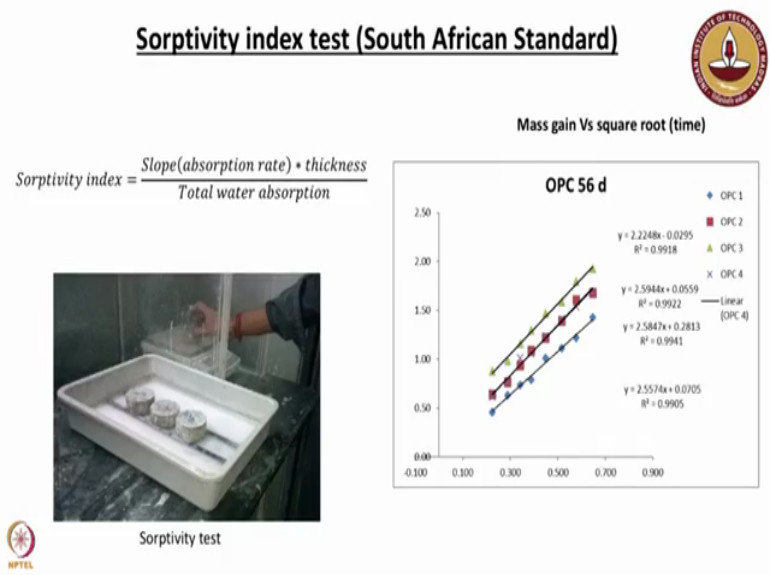

So accordingly you keep measuring the mass of the sample at different time intervals and once you plot the change in mass over time square root of time you take the slope of that curve which will be absorption rate of the moisture inside the sample.

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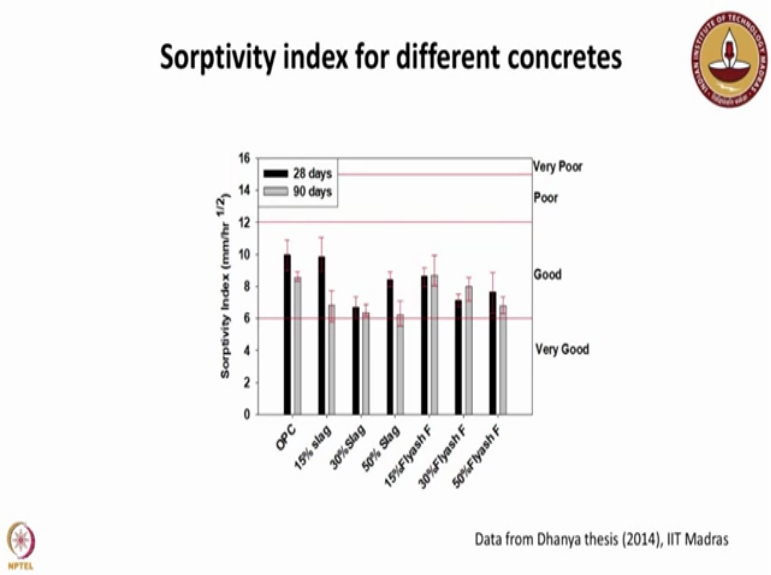

Now we will see a typical graph representative of variation in the sorptivity value with increasing mineral admixtures in the concrete, we can see that with increasing dosage of mineral admixtures the sorptivity value drops drastically and your concrete becomes more resistance to water ingress, this test become more relevant in cases where you have high humidity conditions, moisture is increasing from the offshore sides into the concrete structures or the substructure is being constantly under the water table and there is constant movement of water inside the concrete specimens.

In those cases having a sorptivity measurement as a measurable durability parameter in your performance specification is more representative of the expected durability performance from the real exposure side. The test nearly lasts for about 25 minutes including the sample preparation the lasts for nearly 7 days the sample preparation is for 7 days and the test lasts for about 20, 30 minutes.

It is fairly indicative of the surface absorption rate which becomes a very useful parameter in terms of quality control of concrete structures. So if you are constructing on a site where there is high humidity conditions or constant exposure to moisture, constant rainfall in particular environment or the substructure which is built below the water table in all these cases having a water absorption parameter as durability specification is more indicative of the kind of performance which is expected on the exposure site, thank you.

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Going forward we will see the next experiment which is on gas permeability, we have seen chloride based test and moisture based test and gas also becomes a very critical factor. For example we can have the carbon di oxide penetrating into the sample, reaching the surface of the steel and start to initiate corrosion. So in these critical conditions you need to assist the quality of concrete by means of its gas penetrability characteristics.

So to do this we have the South African based setup so the sample for this is again about 70 mm in diameter and 30 mm in thickness, the sample is code from a 150 mm cube and then the code is sealed on the sides to have unidirectional movement and then this sealed sample is placed in an 50 degree celsius oven for nearly 7 days again to attain a fairly uniform moisture level inside the sample or to bring it to a very dry state, fine because when there is moisture inside the sample it is going to reduce the permeability of the gaseous species into it.

So once you bring the sample out from oven you need to bring it to room temperature and then surround it with a selefon tape so something close to this the tape is just to give a sufficient push to keep the sample held tightly into the rubber collar, this is the typical rubber collar in which sample will be placed this ensures that the sample is held tight in position and the moisture movement happens only in one direction, the sample has to be placed inside the collar so you need to squeeze the sample into the rubber collar so the sample needs to be placed to one end of the rubber collar and then rubber collar will be placed inside a metallic sleeve, the rubber collar will be placed inside a metallic sleeve which will rubber collar in position.

Then we need to place this sample in the OPI setup, so sample will be placed in the position, you need to tighten the lid to keep it up tight and then we will release oxygen so we will fill this chamber in the bottom with oxygen, we will bring it to a pressure of about 100 kilo pascals and we will keep monitoring the drop in pressure level at regular intervals for about 6 hours at a frequency of measurement every 30 minutes.

So this test runs in similar way like your (())(14:18) permeability cell, so we have an initial pressure on the bottom and we will monitor the pressure drop over a period of time. So now the pressurized gas which is there in the bottom of the cylinder moves through the concrete and get released over here, we need to monitor the pressure over time for a period of 6 hours and by using Darcy's law we will measure the permeability value of the concrete and once you have the permeability value the negative logarithm of the permeability value will give an index value which is called the OPI value which is oxygen permeability index.

The range of oxygen permeability index is between 9 to 12 where South African standard has given a classification that if your concrete has an OPI index about 10 the concrete quality is good which is as very high resistance towards permeability when the OPI index is like below 9 they have classified the concrete to be highly permeable, so these qualitative classification can also be used represent the quality of concrete which has been put in place on the structure.

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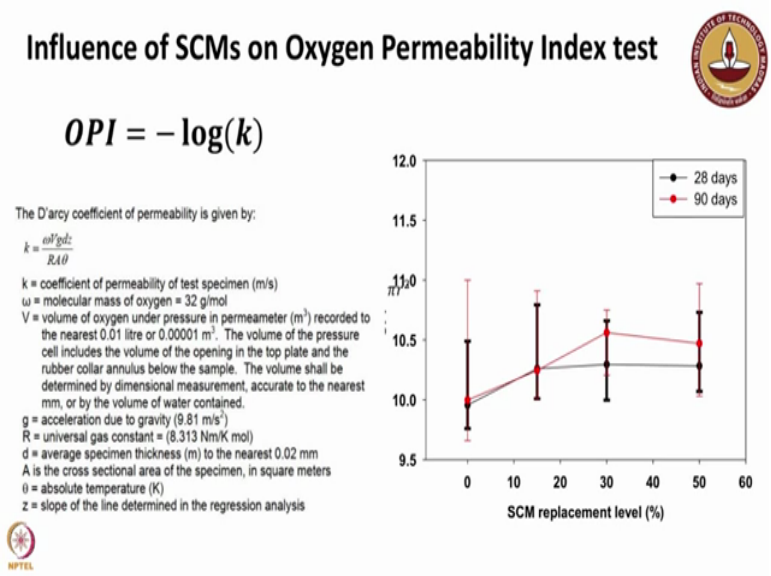

So depending on the mixture proportioning of the concrete or the water cement ratio of the concrete how dense the structure is you will have a difference in the rate at which gas moves

inside your concrete and released. So you will get different permeability characteristics which is measurable using this setup. Since we have seen about the test, let us have a look at some of the cells form OPI in the gas permeability experiments.

As you can see with increasing dosage of fly ashes and slag, we can see a systematic increase in the OPI value which shows the positive benefit of having pozzolanic reaction due to fly ashes and slag within your system which improves the resistance of the concrete to gas permeability.

So we have seen a range of characteristics which can be measured on concrete we have seen chloride based test, we have seen moisture based test and finally we have also seen gas based test, depending on the environment in which the concrete is put in place we need to choose the kind of durability characteristics which has to be measured and measure the performance characteristics which is more suitable for the environment in which the structure is built.

Since we have a variety of test it is necessary to have a proper understanding of the environment in which the structure is built and also detail understanding of the different durability experiments is also required to make an ideal choice of the experiment which has to be done for the structure built in a particular environment, so this were building a proper set of performance specification or kind of durability parameter which has to be assist for a particular structure becomes very crucial in modern construction, thank you.