Hydration, Porosity and Strength of Cementitious Materials
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Lecture – 08
Aggregates

Hi, good morning to one and all, I am K. V. Harish Assistant Professor Department of Civil Engineering, IIT Kanpur. You are watching MOOCS course on Hydration Porosity and Strength of Cementitious Material. Today we will see lecture 8, aggregates; the textbook and reference materials are shown.

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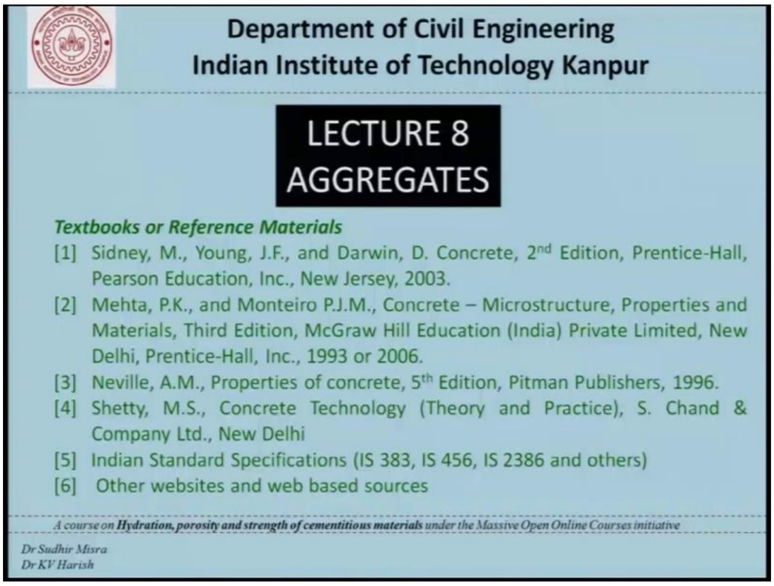

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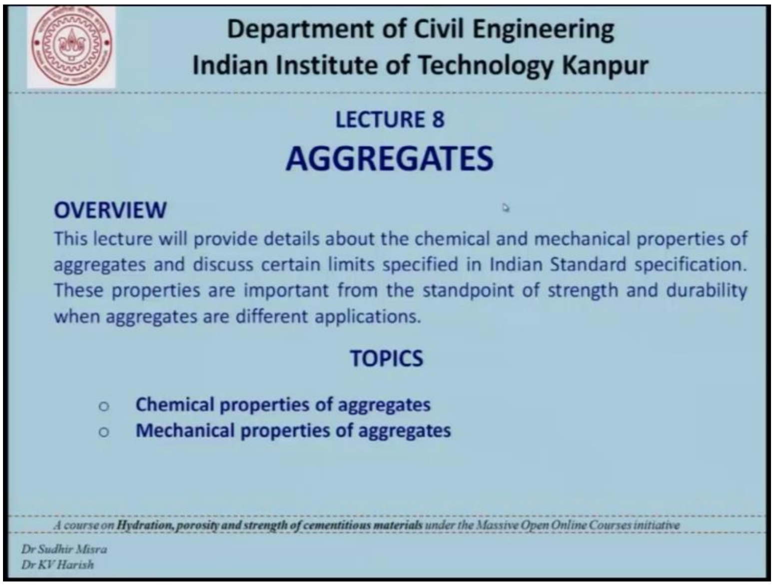

So, in this lecture, we will see topics such as chemical properties of aggregates mechanical properties of aggregates. Remember that in the last lecture we have seen physical properties of aggregates and an overview of this lecture is shown. This lecture will provide details about the chemical and mechanical properties of aggregates and discuss certain limits specified in Indian standard specifications. These properties are important from the standpoint of strength and durability when such aggregates are used for different applications.

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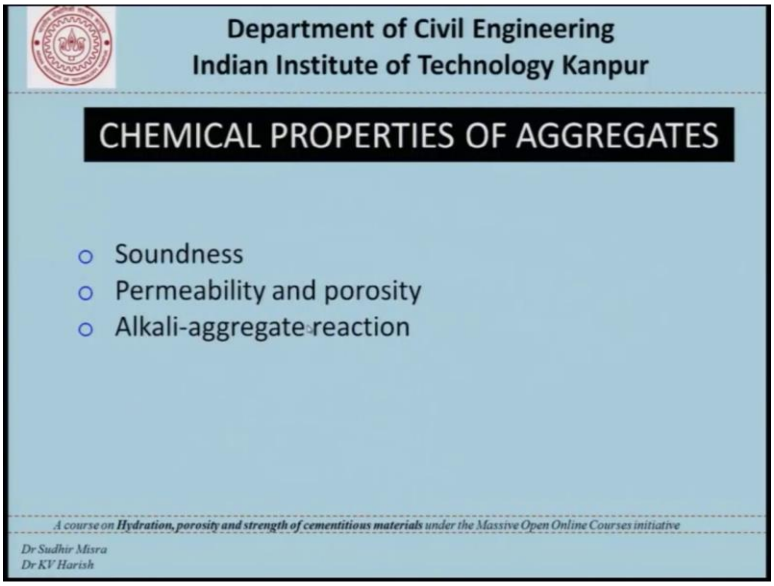

Now, chemical properties of aggregates, there are 3 important chemical properties of aggregates, one is soundness, second one is permeability and porosity third one is alkali-aggregate reaction.

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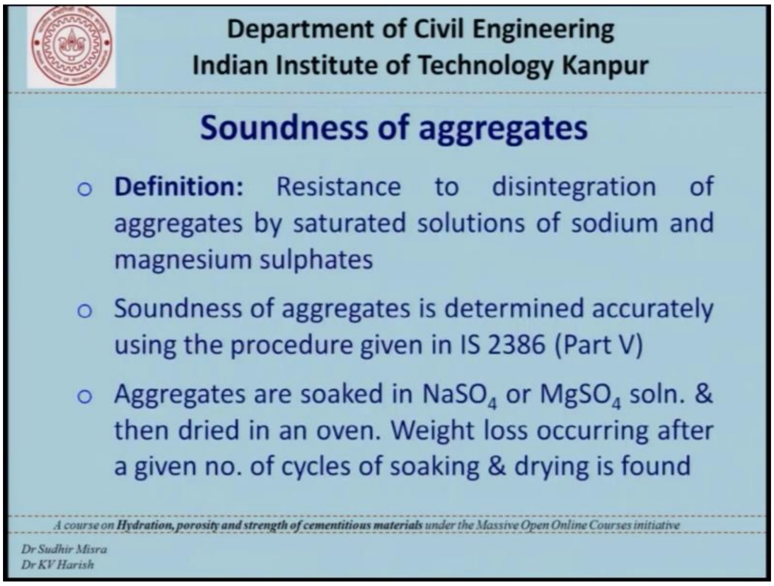

The first one is soundness of aggregates soundness is defined as the resistance to disintegration of aggregates by saturated solutions of sodium and magnesium sulphates soundness of aggregates is determined accurately using the procedure given in IS 2386, part 5. In this method aggregates are soaked in sodium sulphate solution or magnesium sulphate solution and then it is dried in an oven the weight loss occurring after a given number of cycles of soaking and drying is found.

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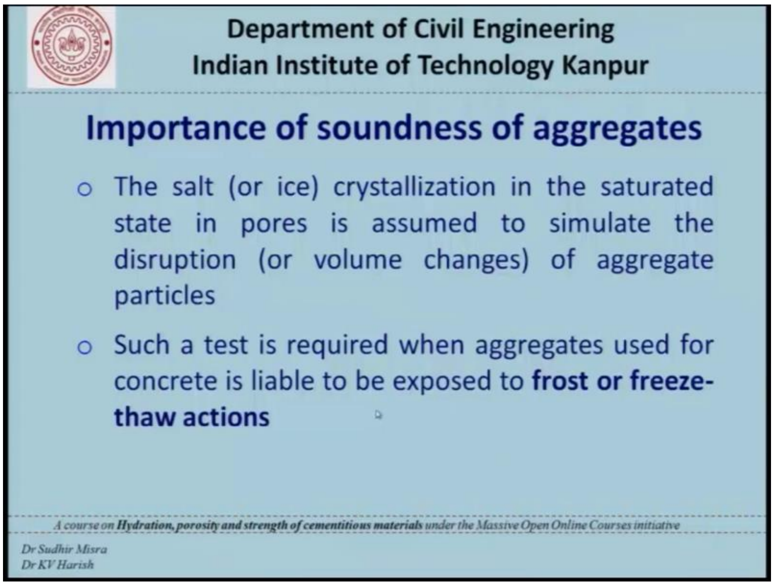

So, what is the importance of soundness? Why do you have to determine soundness of aggregate the salt or ice crystallization in the saturated state in pores is assumed to simulate the disruption or volume changes of aggregate particles such a test is required when aggregates used for concrete is liable to be exposed to frost or freeze thaw actions.

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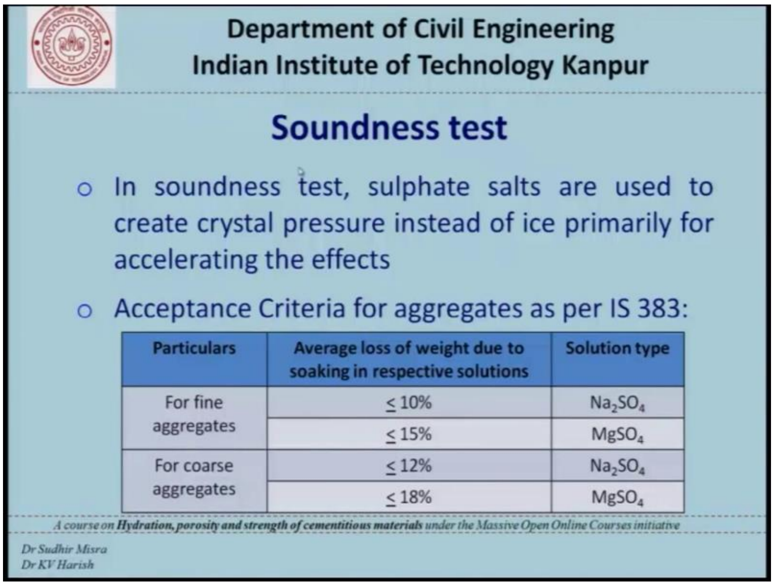

In the soundness test sulphate salts are used to create crystal pressure instead of ice primarily for accelerating the effects if we use ice it will take longer time to make disruption of aggregate if we use sulphate salts or it will cause disruption at a early stage the acceptance criteria that is mentioned in IS 383 for soundness test on aggregates is as follows for fine aggregates the average loss of weight due to soaking in respective solution should be less than or equal to ten percentage if sodium sulphate is used as the salt and the same value should be lesser than or equal to 15 percentage if magnesium is used as the salt.

In the case of coarse aggregates the average loss of weight due to soaking in respective solution should be lesser than or equal to 12 percentage if sodium sulphate is used as salt and the same has to be lower than or equal to eighteen percentage if magnesium sulphate is used as a salt.

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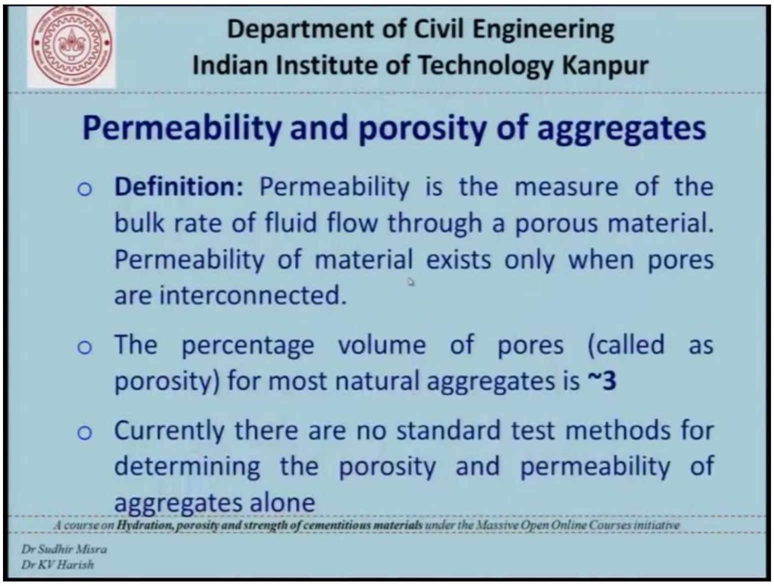

The second important chemical property of aggregates is permeability and porosity permeability is defined as measure of the bulk rate of fluid flow through a porous material permeability of material exist when pores are inter connected.

The percentage volume of pores is called as porosity and for most of the natural naturally occurring aggregates the percentage of pores or porosity is approximately 3 percent which is generally considered to be very low currently there are no test methods for determining the porosity and permeability of aggregates alone.

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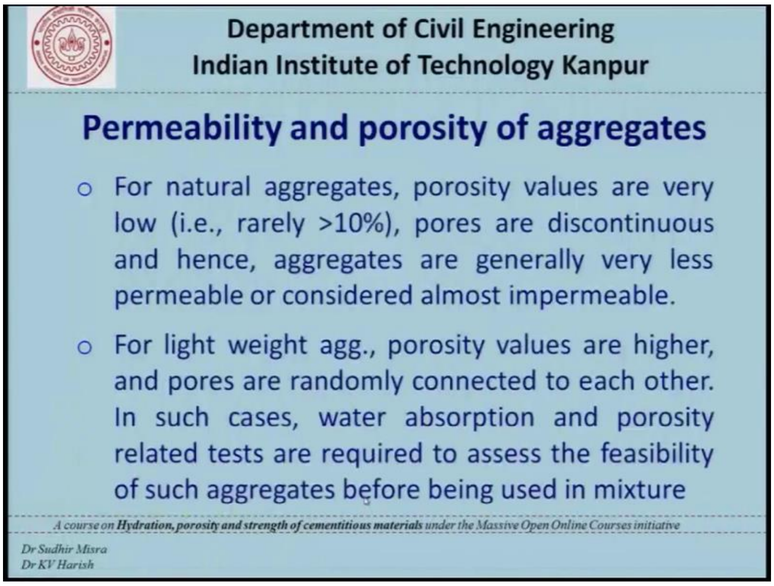

For natural aggregates porosity values are very low as already mentioned rarely it exceeds ten percent and again for natural aggregates we find that the pore are discontinuous and hence aggregates are generally very less permeable or considered almost impermeable.

However the core has also suggested that in addition to natural aggregates light weight aggregates and heavy weight aggregates can also be used for heavy weight aggregates the porosity and permeability values are approximately similar to that of natural aggregates for light weight aggregates the porosity values are higher and pores are randomly connected to each other in such cases water absorption and porosity related tests are required to assess the feasibility of such aggregates before being used in the mixture usually a separate porosity or permeability test for aggregates alone do not exist and what is usually done is when light weight aggregates or other porous aggregates are used the permeability of the mixtures are actually measured using other methods such as Jermons permeability method or a rapid chloride ion permeation test method.

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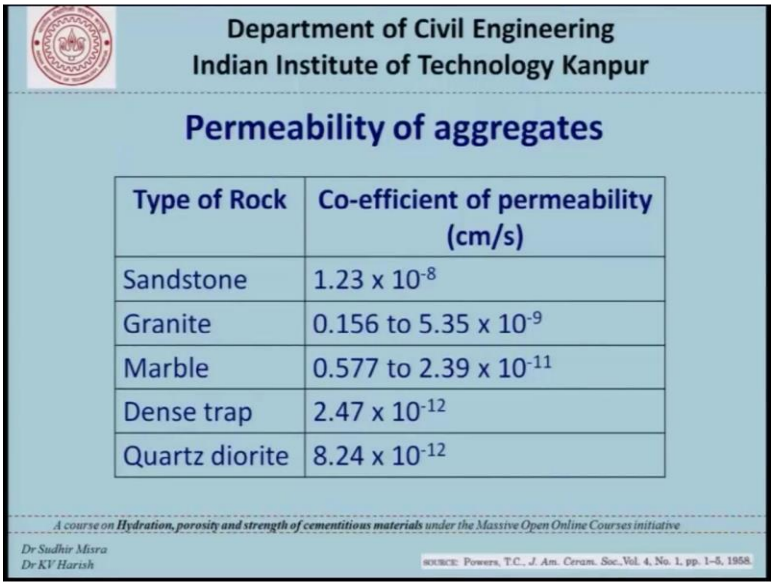

Some approximate values of permeability of aggregates are shown. So, depending upon the type of rock the permeability which is measured in terms of coefficient of permeability substantially differs. So, if you take in the table for sandstone the value of coefficient of permeability is 1.23 into 10 power minus 8 centimetre per second in the case of granite it is 0.156 to 5.35 into 10 power minus 9, likewise for marble dense trap and quartz diorite are all shown here.

So, what you can generally observe is that the coefficient of permeability for aggregates typically ranges from some value into 10 power minus 8 centimetre per second to some value into 10 power minus 12 centimetre per second usually the values mentioned here the magnitude of the values are not absolute values and there are significant variations depending upon the source and type of rocks. So, at a bottom line we can generally say that the coefficient of permeability for rocks or any type of natural aggregates varies from 10 power minus 8 to 10 power minus 12 centimetre per second.

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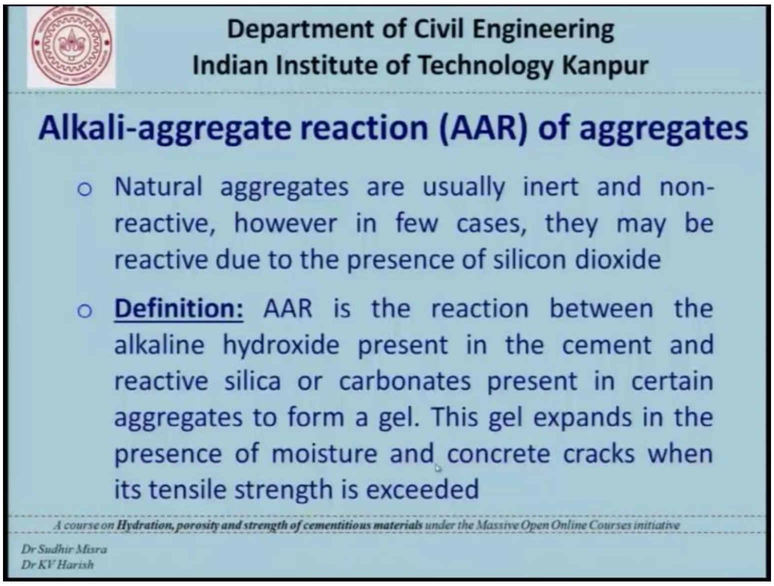

The third important chemical property is alkali-aggregate reaction of aggregates natural aggregates are usually inert in nature and non reactive; however, in few cases they may be reactive primarily because the silicon dioxide present in aggregates could be reactive. So, the definition of alkali-aggregate reactions is as follows alkali-aggregate reaction in this lecture denoted as- AAR is the reaction between the alkaline hydroxide present in the cement and reactive silica or carbonates present in certain aggregates to form a gel. This gel when it comes in contact with moisture expands and the concrete cracks are produced when the tensile strength of concrete is exceeded.

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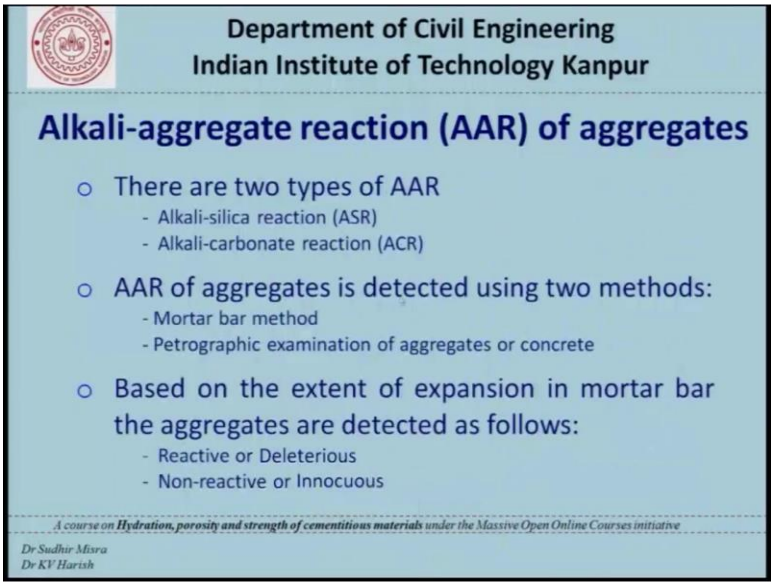

There are typically 2 types of alkali-aggregate reaction one is alkali silica reaction the other one is alkali carbonate reaction the alkali silica reaction is very common and alkali carbonate reaction is usually very rare.

Alkali-aggregate reaction of aggregates is detected using 2 methods one is mortar bar method the other one is petro graphic examination of aggregates or concrete. So, what is done is the mortar bar method is that the expansion of motor bar in the sodium hydroxide solution or any alkaline solution is determined and based on that if the expansion is beyond certain limit then the aggregates are termed as reactive or deleterious if the expansion is lower than the limited value then it is considered as non reactive or innocuous.

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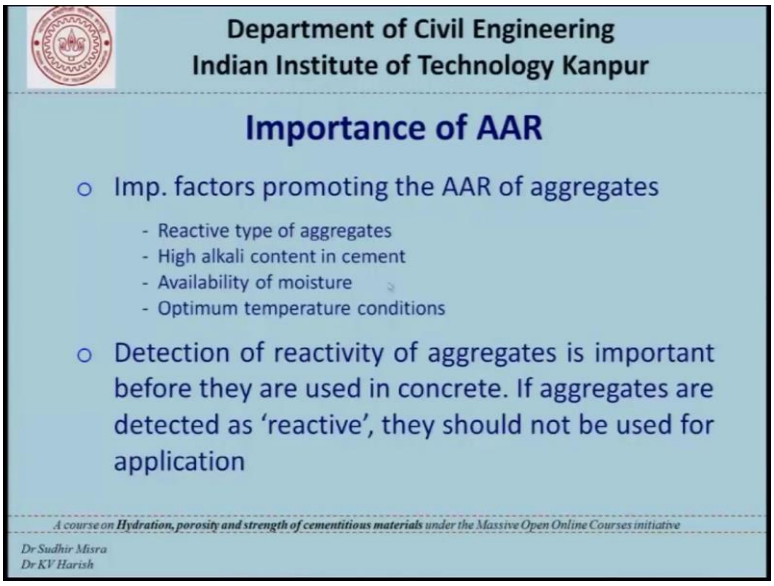

Importance of AAR importance factors promoting the alkali-aggregate reaction of aggregates are as follows when you use reactive type of aggregates instead of non reactive type then it triggers alkali-aggregate reaction if you have high alkali content in cement then that also triggers alkali-aggregate reaction if you have substantial moisture in the mixture then that also triggers alkali-aggregate reaction and when you have optimum temperature conditions that also triggers alkali-aggregate reaction.

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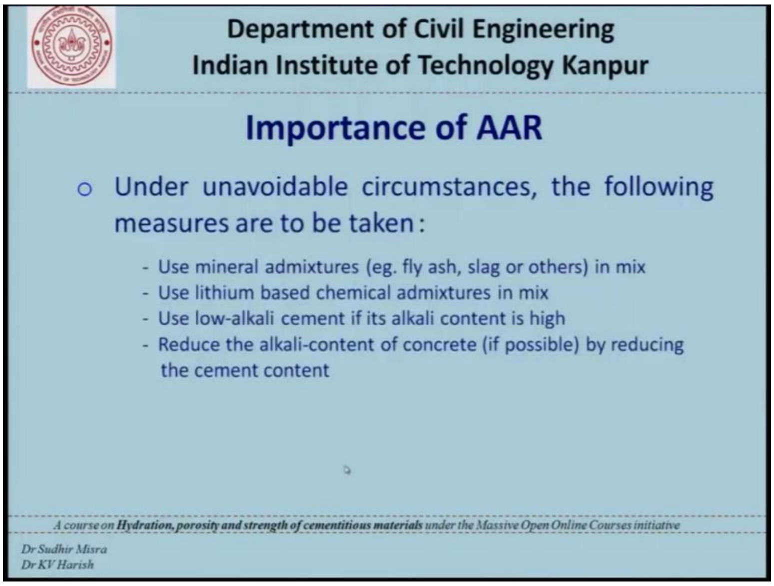

The detection of reactivity of aggregates is extremely important before they are used in concrete if aggregates are detected as reactive they should not be used for application; however, under unavoidable circumstances the following measures are to be taken when you are using reactive aggregates and you cannot avoid using reactive aggregates then you should also use mineral admixtures in the mixture mineral admixtures examples fly ash slag or others and the information about fly ash slag or others will be discussed in detail in other lectures.

The second strategy is use lithium based chemical admixtures in the mixture the third one is use low alkali cement if the alkali content in the existing concrete is high reduce the alkali content of concrete if possible by reducing the cement content you must be very careful when you read the third point and the 4th point the third point is using low alkali cement the 4th point is using low alkali content of concrete. So, one is for cement and the other one is for concrete.

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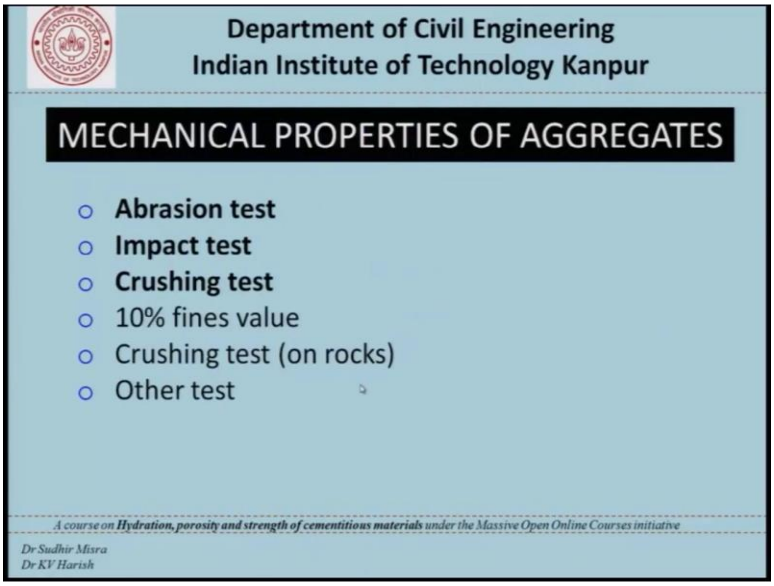

Now, coming on to the mechanical properties of aggregates there are several mechanical tests on aggregates that are performed one is the abrasion test, the second one is impact test, third one is crushing test, fourth one is 10 percentage fines value, fifth one is crushing test, but it is done on rock samples and you also have other tests. So, in this lecture we will concentrate only on abrasion test impact test and crushing test because of because these tests are more important than others.

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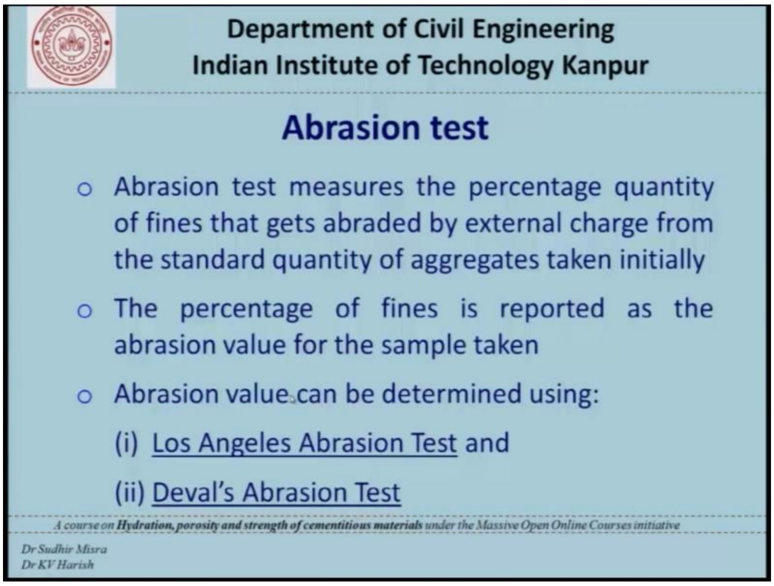

Abrasion test abrasion test measures the percentage quantity of fines that gets abraded by external charge from the standard quantity of aggregates taken initially the percentage of fines is reported as the abrasion value for the sample taken abrasion value can be determined using Los Angeles Abrasion test or Deval's Abrasion test.

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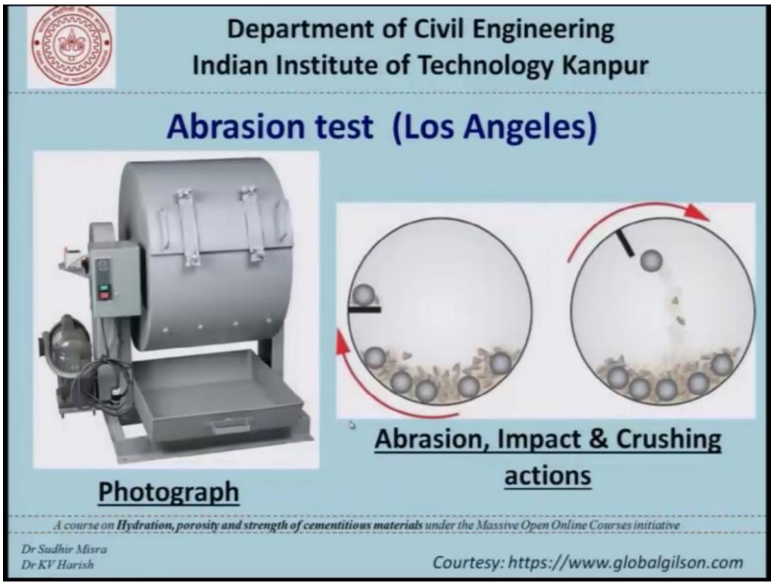

So, what you see in the figure is a typical Los Angeles Abrasion test in the left side you see the equipment that is used for the abrasion test in the right side you have some steel balls and you also have aggregate particles and in the second figure what you see is the movement of the drum where the steel balls are thrown from some height.

So, in the Los Angeles Abrasion test because of the movement of the drum there is three types of actions that are created one is abrasion second one is impact the third one is crushing. So, because of these actions the aggregate breaks into finer particles.

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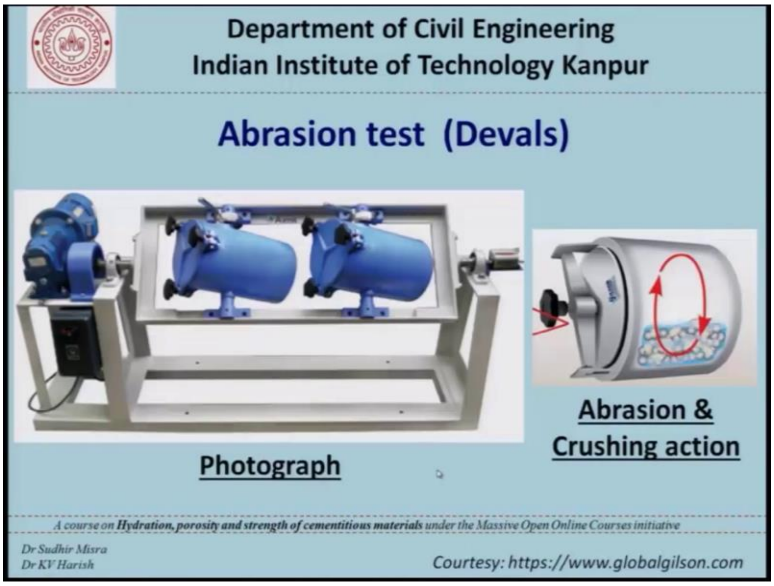

In the second test; Deval's Abrasion test, we find two cylinders; the two cylindrical drums placed at some angle and relatively the size of drums are smaller compared to the Los Angeles Abrasion drum in this test what you see is the rotation of the drum creates only abrasion and crushing action and there is no impact.

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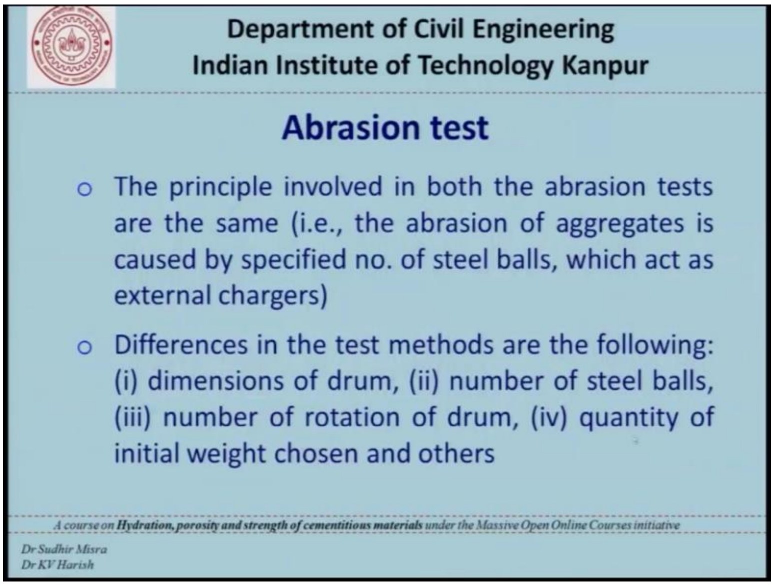

Abrasion test the principle involved in both the abrasion test are the same that is the abrasion of aggregates is caused by specified number of steel balls which act as external charges, but the difference in the test method are the following the dimensions of the drum are different the number of steel balls used in each of the abrasion test is different the number of rotation of drum is different and the quantity of initial weight chosen are also different.

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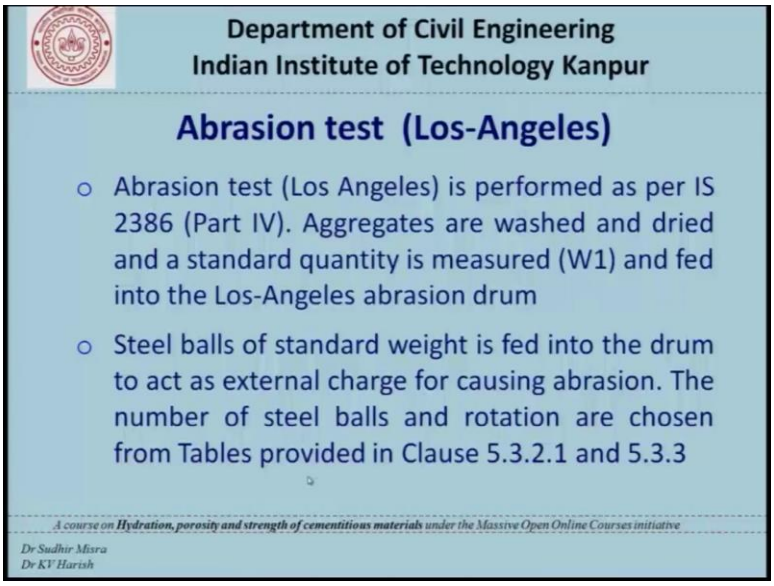

So, in this lecture we will concentrate only on Los Angeles Abrasion test abrasion test is performed as per IS 2386, part 4 aggregates are washed and dried and a standard quantity of aggregate is measured and let us consider it as W 1 and then it is fed into the Los Angeles Abrasion drum the steel balls of standard weight is fed into the drum which will act as external charge for causing the abrasion action the number of steel balls and rotation are chosen from tables provided in clause 5.3.2.1 and 5.3.3.

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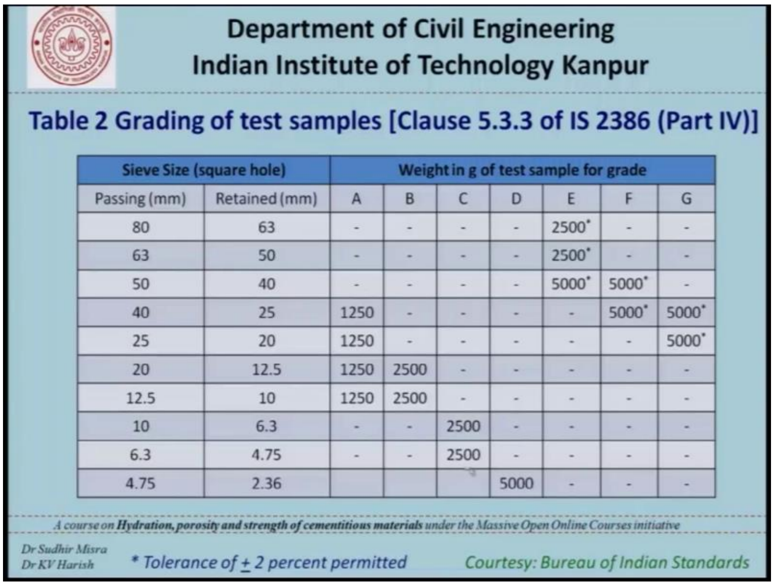

Sieve Size (square hole)		Weight in g of test sample for grade						
Passing (mm)	Retained (mm)	A	B	C	D	E	F	G
80	63	-	-	-	-	2500*	-	-
63	50	-	-	-	-	2500*	-	-
50	40	-	-	-	-	5000*	5000*	-
40	25	1250	-	-	-	-	5000*	5000*
25	20	1250	-	-	-	-	-	5000*
20	12.5	1250	2500	-	-	-	-	-
12.5	10	1250	2500	-	-	-	-	-
10	6.3	-	-	2500	-	-	-	-
6.3	4.75	-	-	2500	-	-	-	-
4.75	2.36				5000	-	-	-

So, the clause 5.3.3 of IS 2386 is shown where you have approximately 2 columns, in one column you have the sieve size and within that you have 2 sub columns one is passing size the other one is retained size the passing size ranging from 80 mm in the top to 4.75 at the bottom and in the retained size you have 63 in the top and 2.36 at the bottom.

In the second column which is weight in grams of the test sample for specific grade we have about 7 grades A, B, C, D, E, F and G and these 7 grades are actually defined in another clause.

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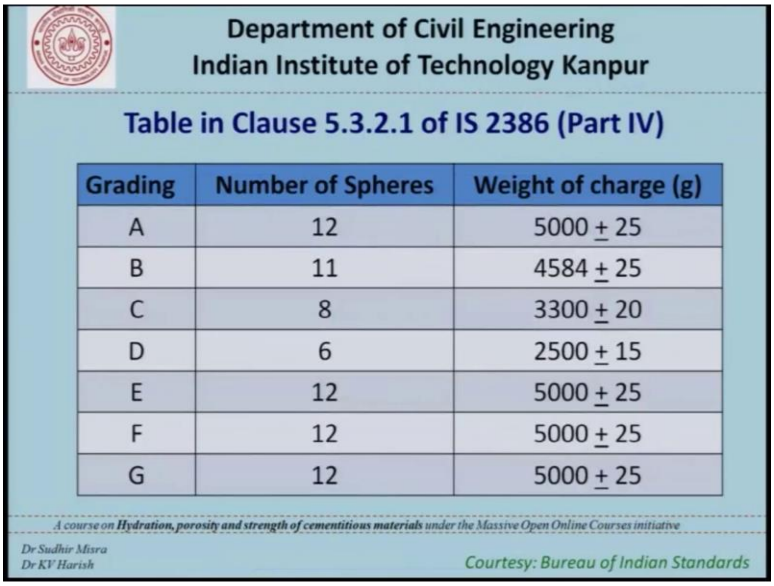

So, let me go to the next table. So, this table is from clause 5.3.2.1 of IS 2386 and here you see that the grading A to G and you also have number of spheres and weight of material to be used as per each grading. So, if you take grading a 12 number of spheres have to be used and 5,000 plus or minus 25 grams should be taken initially.

So, let me go to the previous table. So, here you have A to G and for each of the grade you have the passing size and retained size specified and depending upon that we have to take the specific weight that is provided here. So, in this table say for grading a you have 1250, if the passing size is 40 mm and the retained one is 25 mm and likewise for others, similarly you also have values for B to G remember that there is a star that is provided for some of the values indicating that you do not have to take the exact weight of these quantities there could be a tolerance of plus or minus 2 percentage.

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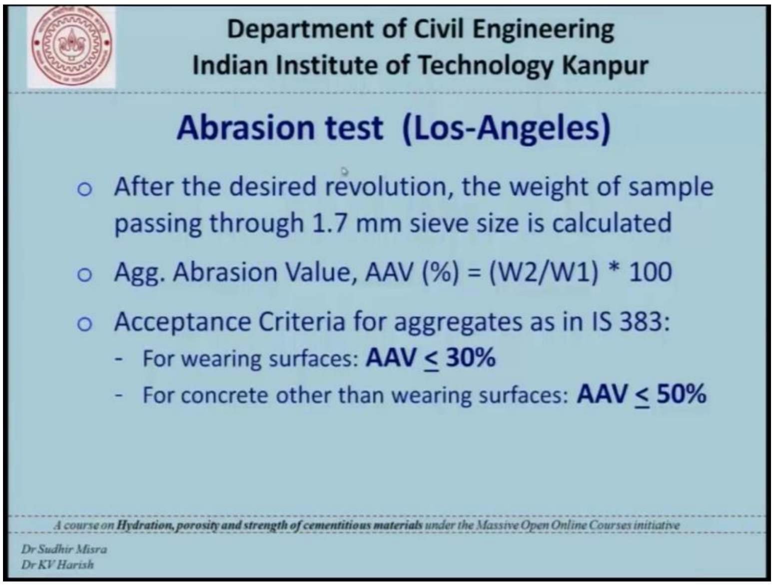

So, after the desired revolution the weight of sample passing through 1.7 mm sieve size is calculated and abrasion value denoted as AAV in percentage is equal to W 2 by W 1 into 100 the acceptance criteria for aggregates as indicated in IS 383 is as follows if aggregates are to be used for wearing surfaces such as pavement and other applications the AAV value should be lesser than or equal to 30 percent.

if the aggregates are used for concrete application other than wearing surfaces in that case the value should be lesser than or equal to 50 percentage point if the values are greater than 30 percentage for wearing surfaces or greater than 50 percentage for concrete other than wearing surfaces those aggregates should be completely rejected.

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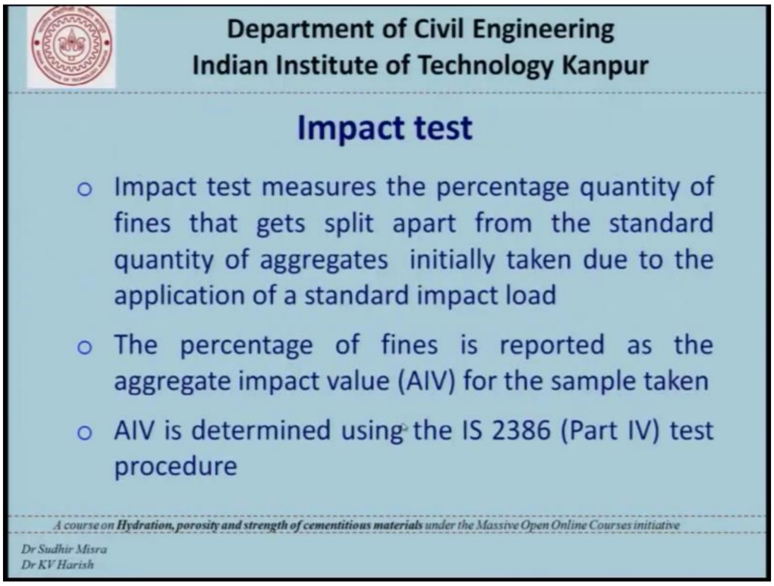

The second test that we will see is the impact test impact test measures the percentage quantity of fines that gets split apart from the standard quantity of aggregates initially taken due to the application of a standard impact load the percentage of fines is reported as the aggregate impact value for that particular sample taken the aggregate impact value is denoted by AIV and it is determined using the IS 2386 part 4 test procedure.

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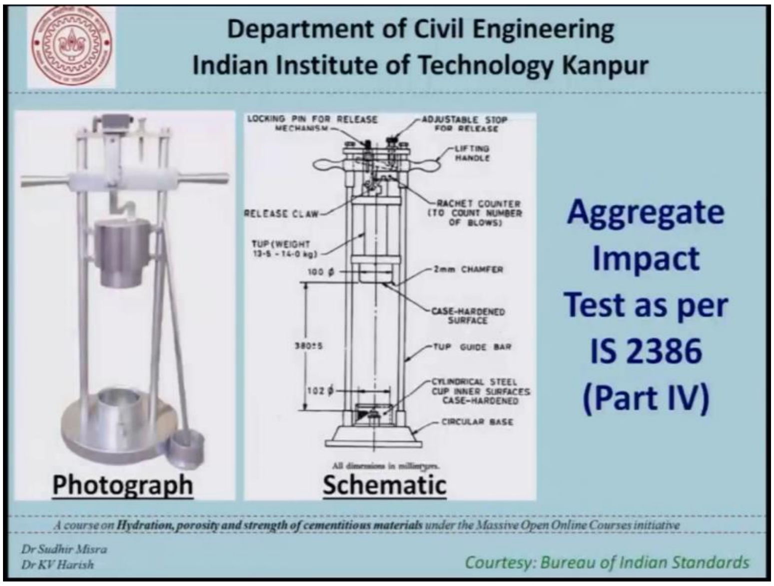

So, the equipment looks like this. So, in the left you have a typical photograph of the equipment the right you have the in the centre you have the schematic diagram.

So, what you see is that basically you have a cylindrical steel cup at the bottom where the aggregates to be tested or taken and it is placed in a frame impact test frame where you see that there is a circular base and a tub guide bar and also standard weight and you also have some lifting handles for that way and also there is some release mechanisms. So, what you basically do in this test is you take some aggregates in the steel cup and fill it until the top by giving 3 tamping each layer and then the standard weight is basically released from a standard height and in this case 380 mm plus or minus 5 mm is the standard height. So, the weight is basically released from the standard height and the weight is allowed to fall on the aggregate and this process is repeated multiple times and after certain number of times the aggregates are taken out and it is sieved through a 2.3 mm sieve.

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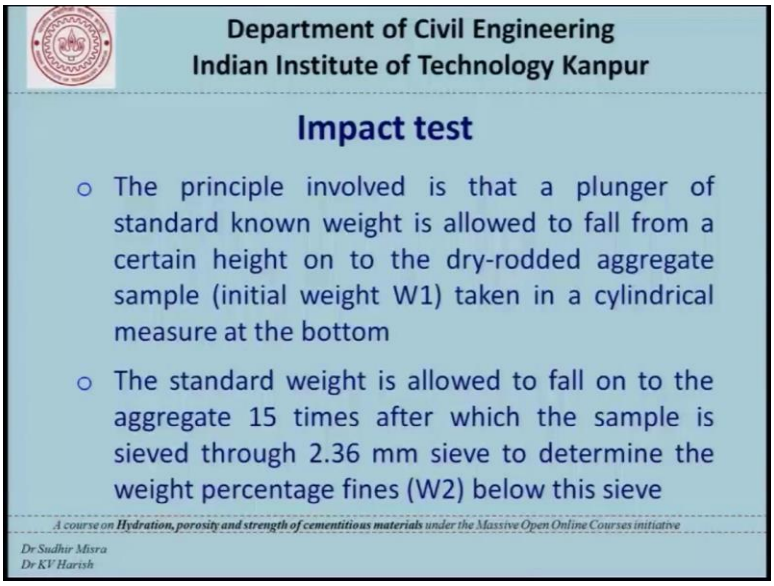

The principle involved in the impact test is that a plunger of standard known weight is allowed to fall from a certain height on to the dry rodded aggregate sample and let us assume that the initial weight of the sample is W 1 and this is taken in the cylindrical measure at the bottom the standard weight is allowed to fall on to the aggregate 15 times after which the sample is sieved through 2.36 mm sieve and the percentage passing through this 2.36 sieve is determine and let the weight be W 2.

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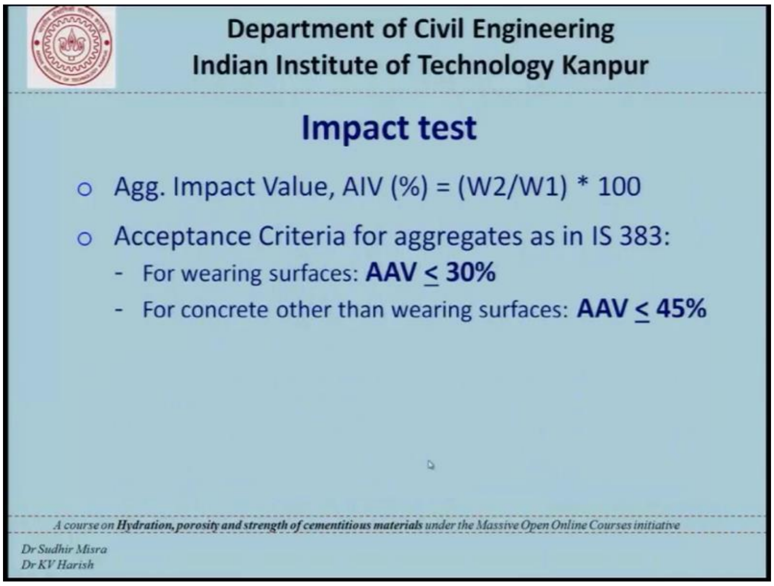

The aggregate impact value AIV expressed in percentage is determined by calculating W 2 divided by W 1 into 100 the acceptance criteria for impact test is as follows for wearing surfaces the aggregate impact value should be lesser than or equal to 30 percent for concrete other than wearing surfaces the aggregate impact value should be lower than or equal to 45 percentage remember that if these values are greater than 30 percentage for wearing surfaces and greater than 45 percentage for concrete other than wearing surfaces then that aggregate sample is rejected and cannot be used for that application.

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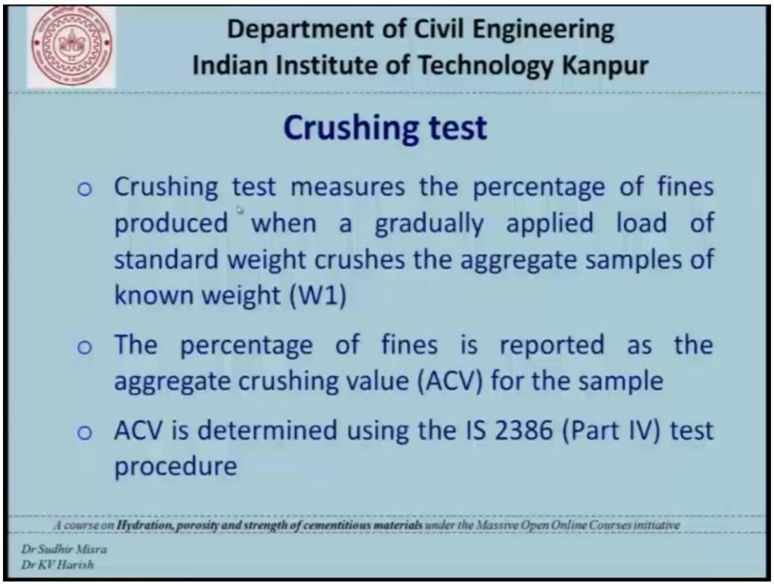

The third important test is crushing test crushing test measures the percentage of fines produced when a gradually applied load of standard weight crushes the aggregate samples of known weight and in this case the known weight is taken as W 1 the percentage of fines is reported as the aggregate crushing value ACV for that particular sample taken and ACV is determined using the standard IS 2386 part 4 test procedure.

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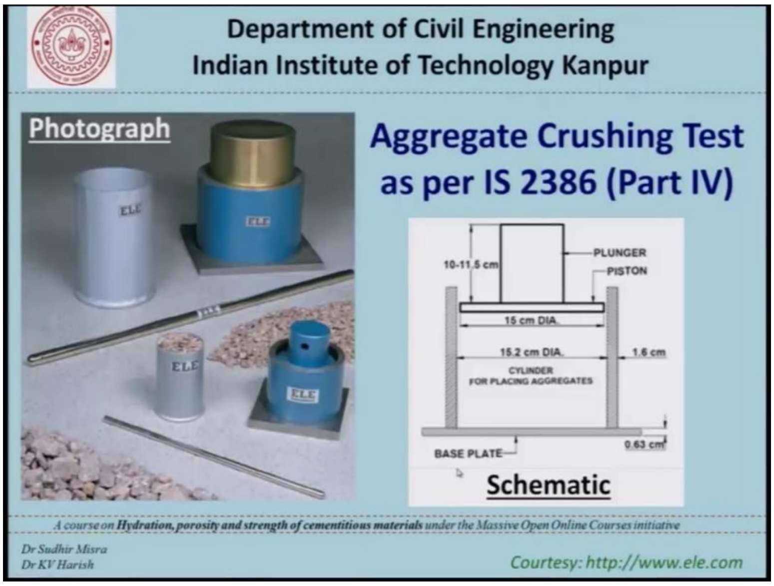

So, in this figure you see the typical equipments or small tools that you use in this test. So, here you have a small cylindrical measure and you have a plunger of standard weight and a piston which is attached to a plunger has diameter approximately slightly lower than the diameter of the cylindrical measure. So, if you carefully see the cylindrical measure has a diameter of 15.2 centimetres and the piston has a diameter of 15 centimetre. So, that there is about 0.1 centimetre on either side so that the plunger can safely go inside. So, the aggregates are initially taken in the cylindrical measure.

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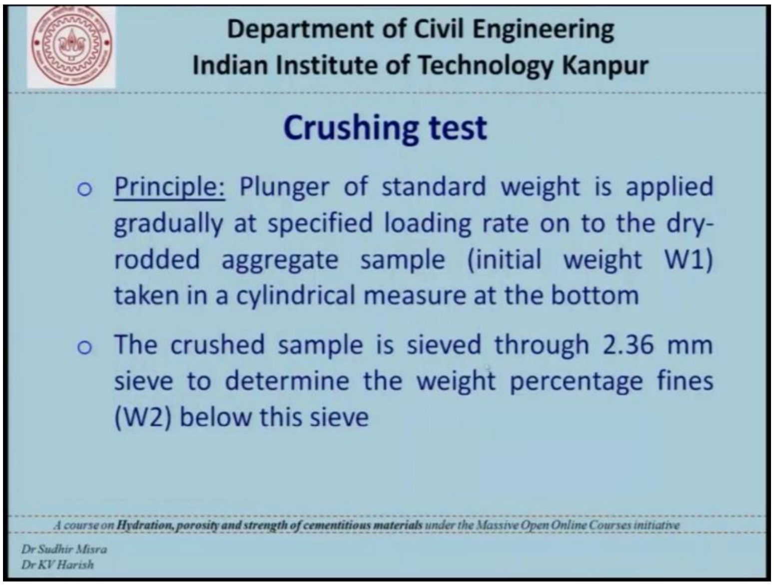

The principle involved is as follows a plunger of standard weight is applied gradually at specified loading rate on to the dry rodded aggregate sample the initial weight is considered as W 1 and the aggregate is taken in a cylindrical measure and kept at the bottom the crushed sample is sieved through 2.36 mm sieve to determine the weight percentage fines below this sieve and the weight of the fines is measured as W 2.

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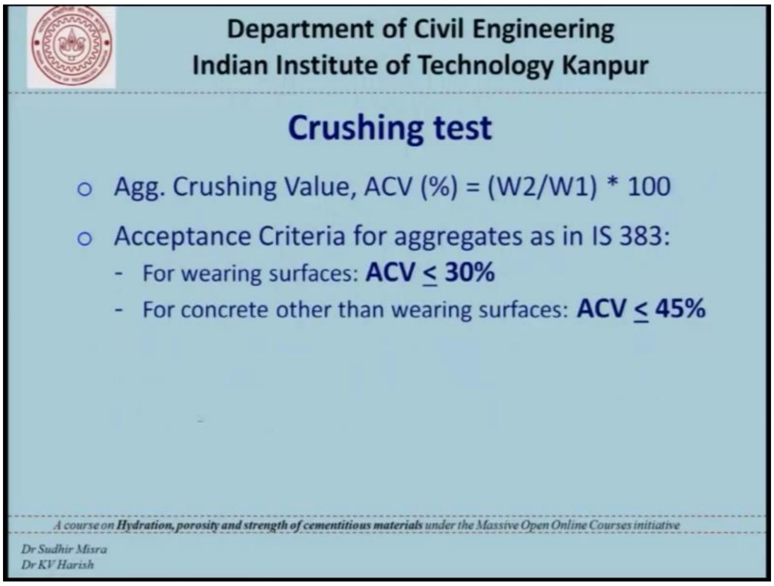

The aggregate crushing value ACV in percentage is equal to W 2 by W 1 into 100 the acceptance criteria for aggregates as in IS 383 specification for crushing test is as follows for wearing surfaces the ACV value should be lower than or equal to 30 percentage.

For concrete other than wearing surfaces the ACV value should be lower than or equal to 45 percentage and any aggregates that do not meet these criteria, they will be rejected for that particular application with this we come to an end for this lecture.

Thank you.