Hydration, Porosity and Strength of Cementitious Materials

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Lecture – 05
Portland Cement

Hi, Good Morning to one and all, I am K V Harish, assistant professor, Department of Civil Engineering, IIT Kanpur, you are watching MOOCs lecture course on hydration porosity and strength of cementititous material.

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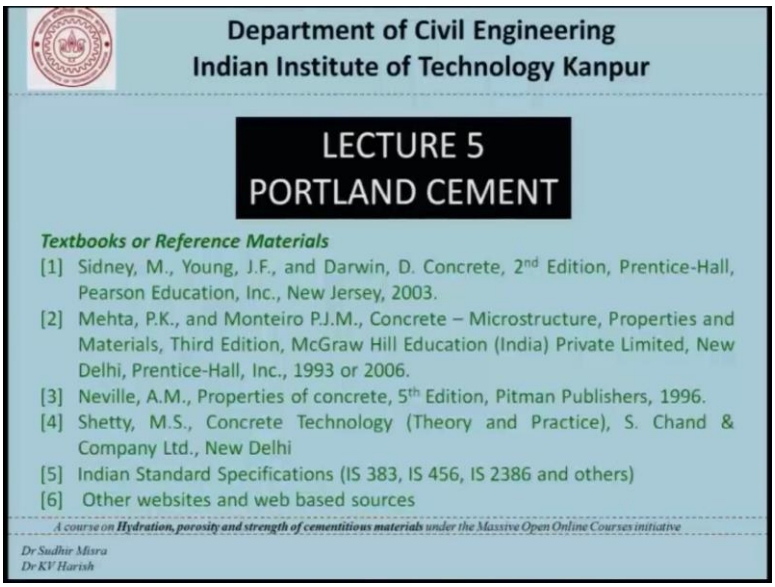

We will be seeing today lecture 5, Portland cement, this is a continuation to the previous lecture the textbooks and reference materials for this lecture is provided.

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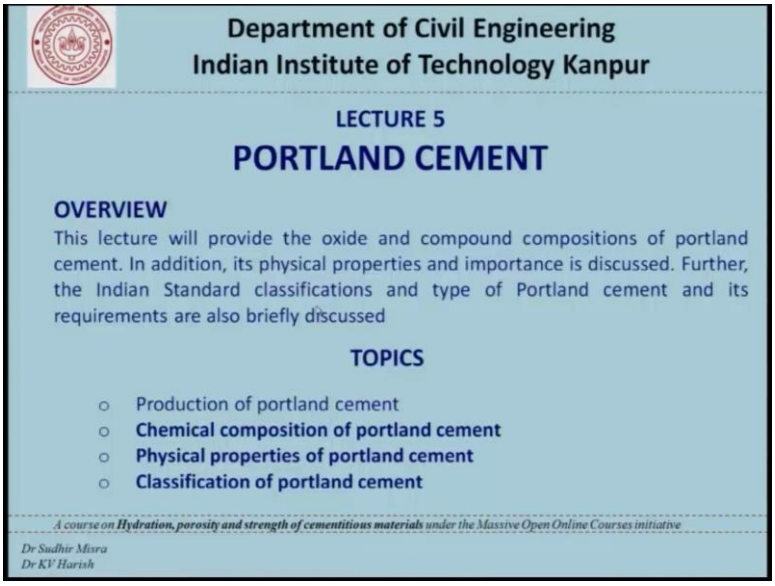

The topics that that will be covered in this lecture are as follows; chemical composition of Portland cement, physical properties of Portland cement, classification of Portland cement. The overview is as follows: this lecture will provide the oxide and compound compositions of Portland cement, in addition its physical properties and importance is discussed further the Indian standard classifications and type of Portland cement and its requirements are also briefly discussed.

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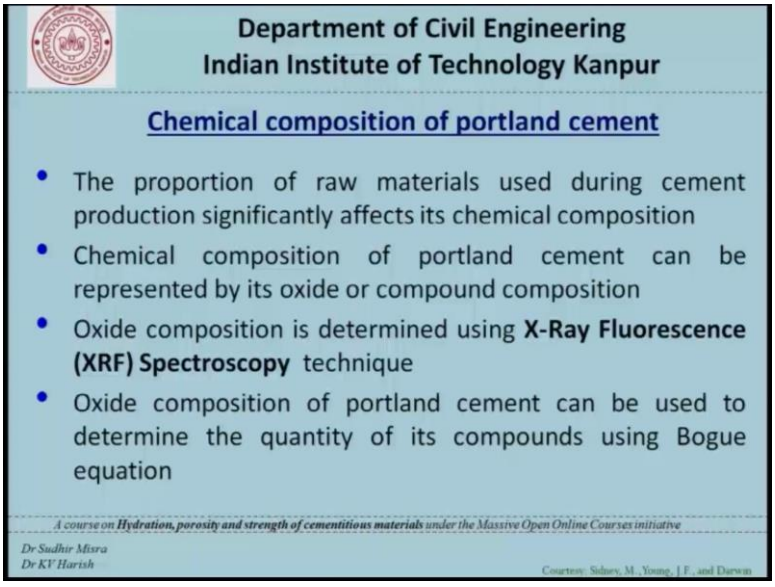

Chemical properties of Portland cement the proportion of raw materials primarily limestone clay and others that are used during cement production significantly affects its chemical composition. However, these proportions are well controlled at the plant level itself chemical composition of Portland cement can be represented either in terms of oxides or in terms of compounds the oxide composition are usually determined using X-Ray fluorescence spectroscopy technique oxide composition of Portland cement can be used to determine the quantity of compounds using Bogues equation.

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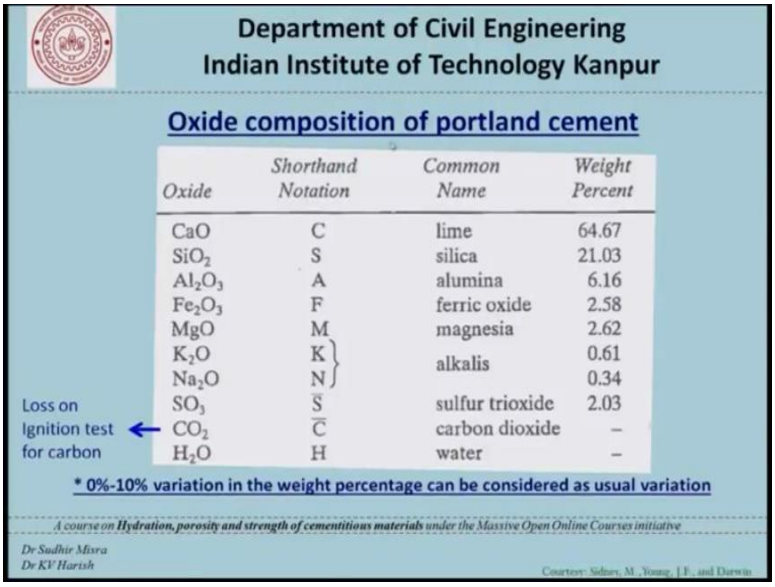

The oxide composition of Portland cement here in the left you find the different oxides partly we have already discussed in the previous lecture. So, oxide start from calcium oxide, silicon dioxide, aluminium oxide and it goes up to sulphur tri oxide, the short notations are shown the common names that are used for these oxides are listed calcium oxide for lime silicon dioxide for silica aluminium oxide for alumina iron oxide for ferric oxide magnesia alkalis sulphur trioxide and others.

The weight percentages of these oxides are very important calcium oxide is about 64 percent, silicon dioxide is about 21 percent, aluminium oxide is about 6 percent, iron oxide is 2.5 percent and others are minor oxides it may be remembered that exact quantity of these oxides sorry not important, but you may understand that there will be 0 to 10 percentage variation in these amounts.

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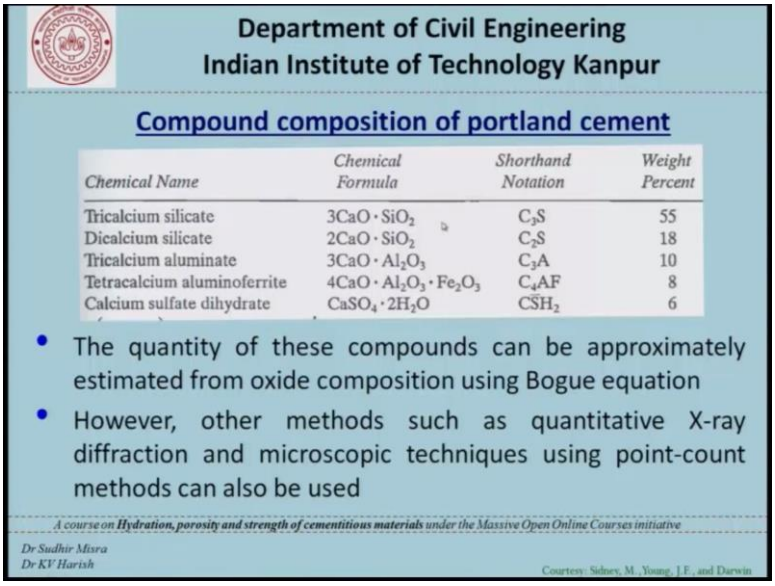

Now, compound composition of Portland cement as already discussed cement contains 4 main compounds Tri-calcium silicate, Di-calcium silicate, Tri-calcium aluminate, tetra-calcium alumino-ferrite and calcium sulphate, dehydrate or gypsum and the weight percentage are very important C3S is 55 percent, C2S is 18 percent, C3A is 10 percent, C4AF is 8 percent and gypsum is 6 percent the quantity of these compounds can be approximately estimated from oxide composition from Bogues equation which will be discussed in the next slide; however, other methods such as quantitative X-Ray diffraction and microscopic techniques using point count methods can also be used.

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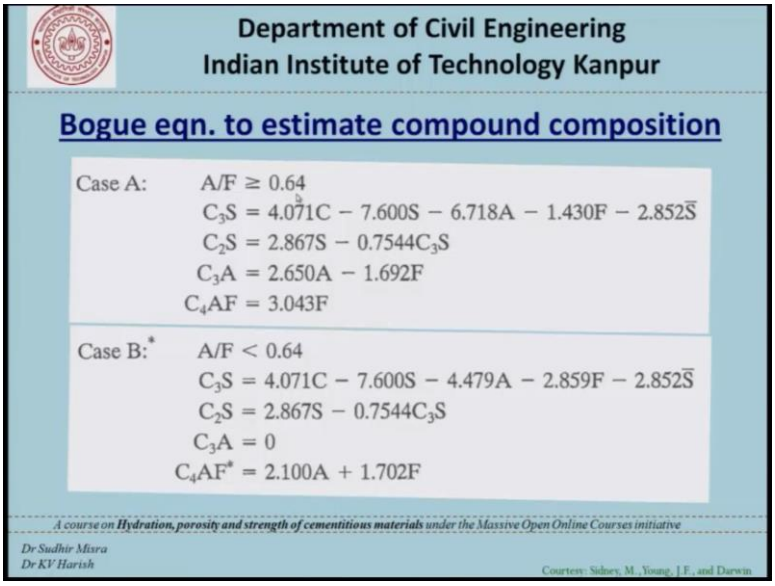

Now, the Bogues equation to estimate compound composition is shown here there are 2 different cases that occur case A and case B depending upon the ratio of aluminate and ferrite that is present in the Portland cement for aluminate to ferrite ratio greater than or equal to 0.64 these set of formulas are used to find out C3S content C2S content C3A content and C4AF.

Remember in all these formulas the short notations are used or abbreviation. So, C refers to cap, S refers to silicon dioxide, A refers to aluminium oxide and so on and for each compounds for case B where the aluminate to ferrite ratio is lower than 0.64, these set of formulas are used and again C, S and A refers respective oxides that are mentioned previously they are short hand notations. So, for people who are taking exams these set of equations may be given at a later stage and you may have to use these equations to solve some problems either assignment problems or exam questions.

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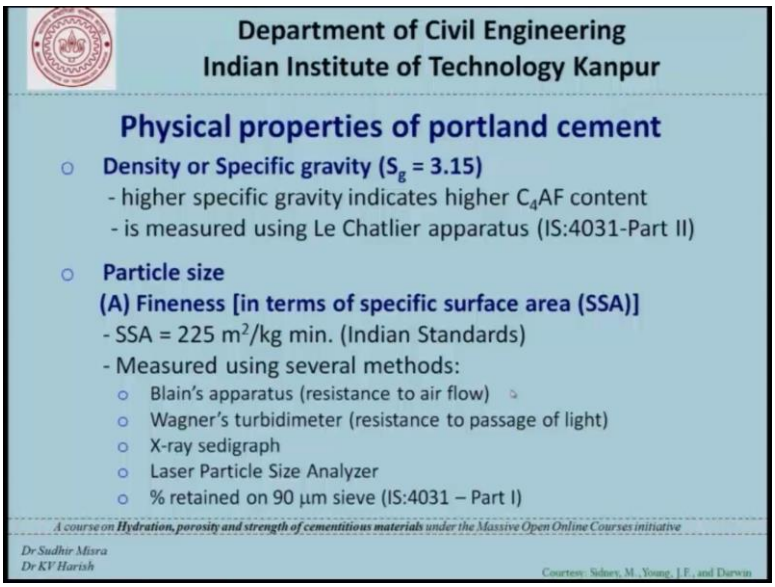

Physical properties of Portland cement; so, the main important properties of Portland cement alone are discussed first one is density or specific gravity the specific gravity of Portland cement typically is 3.15 that value is very important higher specific gravity usually indicates that the quantity of tetra calcium alumino ferrite is higher in Portland cement the density or specific gravity is measured using Le chattier Apparatus and the procedure for this is given in IS 4031; part 2.

The second important property is particle size and particle size can be represented in various forms one form is fineness and fineness is expressed in terms of specific surface area or shortly referred as SSA; SSA approximately should be 225 metre square per kg at a minimum as per Indian standards cements that have lower fineness are usually rejected.

Fineness is measured using several methods blains apparatus where the principle used is resistance to air flow Wagner's turbidimeter where the principle used is resistance to the passage of light X-Ray sedigraph laser particle size analyzer and percentage retained on ninety micron sieve as defined in IS 4031 part 1.

Fineness is a very important property of Portland cement that can affect the composites that are produced from Portland cement higher the cement fineness.

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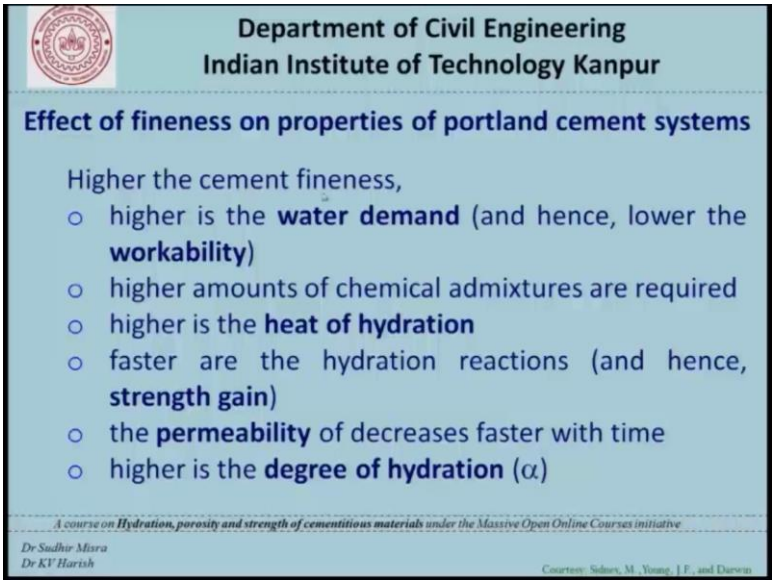

Higher is the water demand and hence lower is the workability what is workability and other things will be discussed in other lectures higher amounts of chemical admixtures are required higher will be the heat of hydration faster or the hydration reactions and hence strength gain the permeability of the mixture decreases faster with time higher is the degree of hydration. So, when Portland cement is finer more particles are readily available to react and there are some positives and some negatives in all these points shown.

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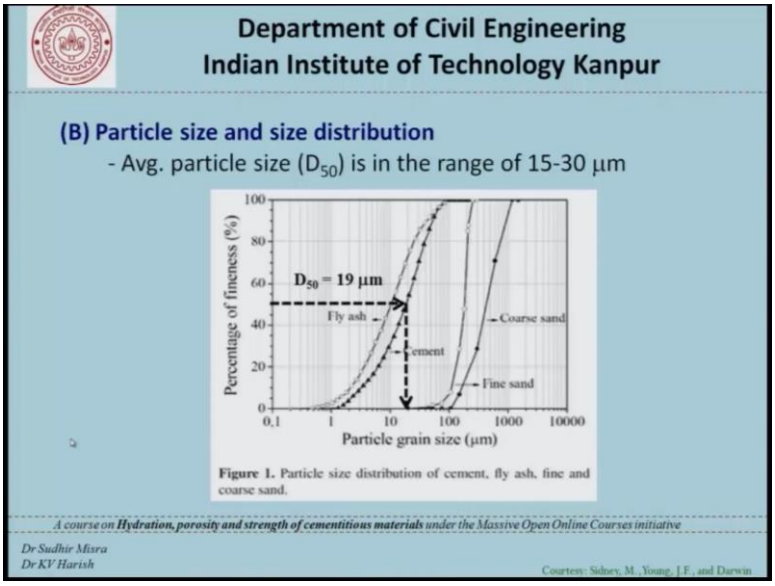

The second way of representing size is particle size or size distribution the average particle size d 50 of cement particle is usually in the range of fifteen to thirty microns a simple figure is shown where in the particle or grain size is taken in the x axis and percentage of fineness is taken in the y axis or cumulative percentage passing is taken in the y axis remember here that the x axis is not in the normal scale it is expressed in log scale. So, in the figure there are 4 different particle size materials are shown one is the coarse sand the other one is the fine sand the other one is the cement and other one is other supplementary cementing materials like fly ash the purpose of this figure is to get some comparative idea about the particle size of cement with regard to other materials.

As you can see that the cement particles have approximately D 50 value of 19 micron and some supplementary cementing materials are finer than cement and the fine sand and coarse sand the particle sizes are much higher.

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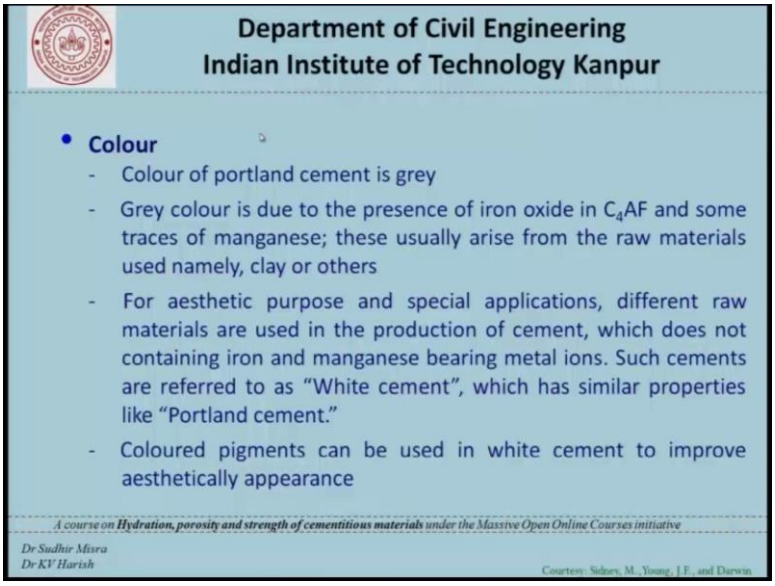

The third important property is colour Portland cement is usually grey in colour and the grey colour is primarily due to the presence of iron content in the raw materials. So, grey colour is due to the presence of iron oxide in C4AF and some traces of manganese these usually arise from the raw materials used namely clay or others for aesthetic purpose and other special applications different raw materials are used in the production of cement which does not contain iron or manganese bearing metal ions such cements are referred to as white cement which have similar properties like Portland cement and many times such cements are required. So, that coloured pigments can be added to improve the aesthetic appearance of the mixture.

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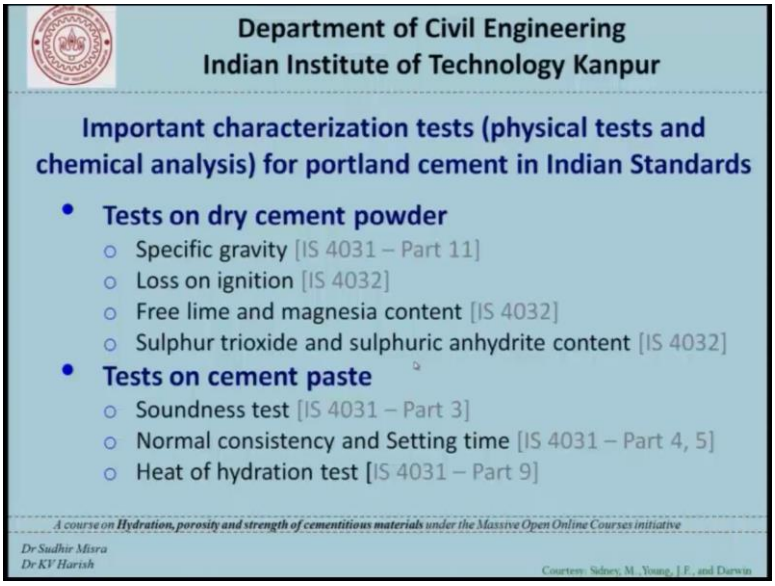

Now, classification of Portland cement important characterization test for Portland cement in Indian standards are listed some tests are for dry cement powders some tests are for cement paste and some tests are for cement mortars. So, for dry cement powder one may have to find out the specific gravity loss on ignition free lime and magnesia content sulphur trioxide and sulphuric anhydrite content. So, these tests are done as per Indian standard 4031; part 11 and IS 4032, remember IS 4031 and IS 4032 test on cement paste soundness test normal consistency and setting time test heat of hydration test all these things are done on cement paste and again IS 4031 is part 3; part 4, part 5 and part 9 are used.

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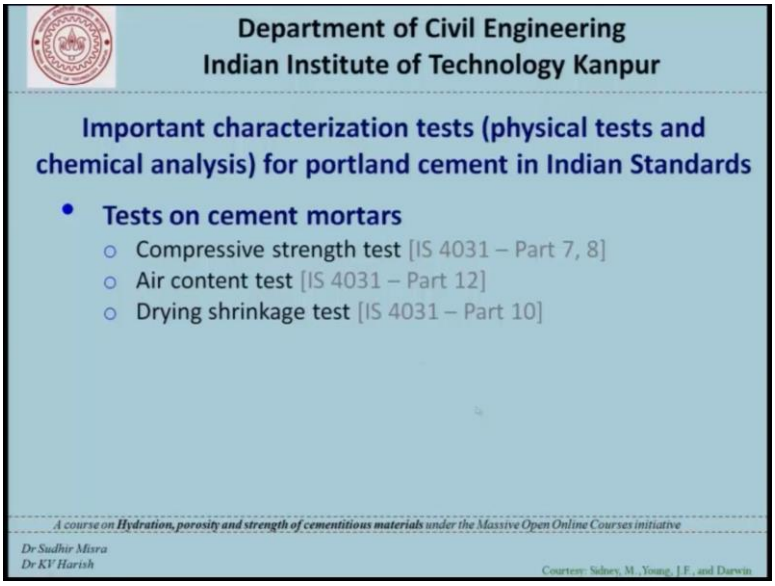

Test on cement mortars includes compressive strength test air content test drying shrinkage test as per IS 4031 part 7, 8, 12 and 10 respectively, characterization test also indicates that a particular type of cement requires certain properties before being used for any application.

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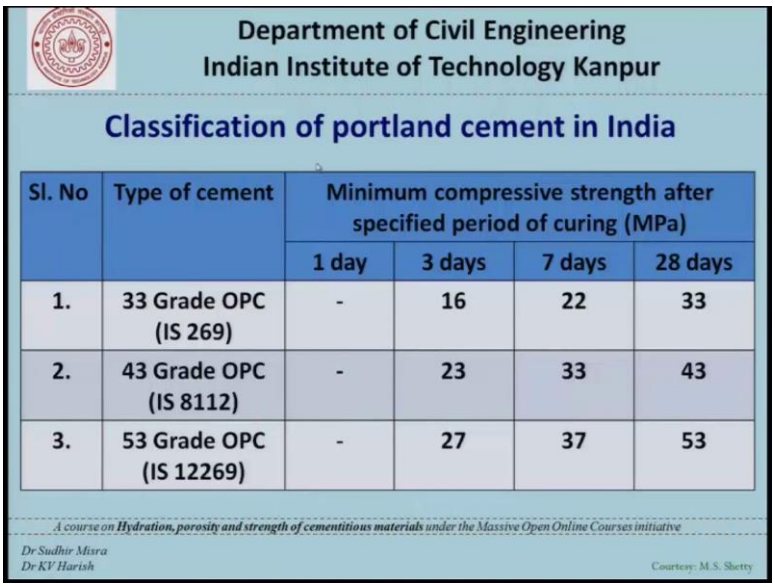

The Portland cement in India is classified into 3 different types in the table what you see is 33 grade ordinary Portland cement, 43 grade ordinary Portland cement and 53 grade ordinary Portland cement and these 3 grades are as per Indian standard specifications,

269, 8112 and 12269 respectively. In this table, the minimum compressive strength after specified period of curing for all these cements is also specified as you can see that the Indian standards specify 1 day, there days 7 days and 28 days for all these type of cements one day is not specified 3 days 16 MPA, 23 MPA and 27 MPA; 7 days 22, 33 and 37, 28 days, 33, 43 and 53.

As you can see that the name 33 grade arises from the compressive strength that is obtained at 28 days and the grade 43 comes from the strength obtained for that cement at 28 days and 53 grade, the strength that is obtained for that cement at 20 days and you can also see that these are the minimum strengths that these type of cements should provide after 28 days and you also see that all these cements 33 grade, 43 grade and 53 grade have the same chemical composition and for the same chemical composition one cement produces higher compressive strength than the other the primary differences between these cements will be in the fineness of the particular cement for example, the 33 grade the fineness is much lower compared to the 43 grade and compared to the 53 grade.

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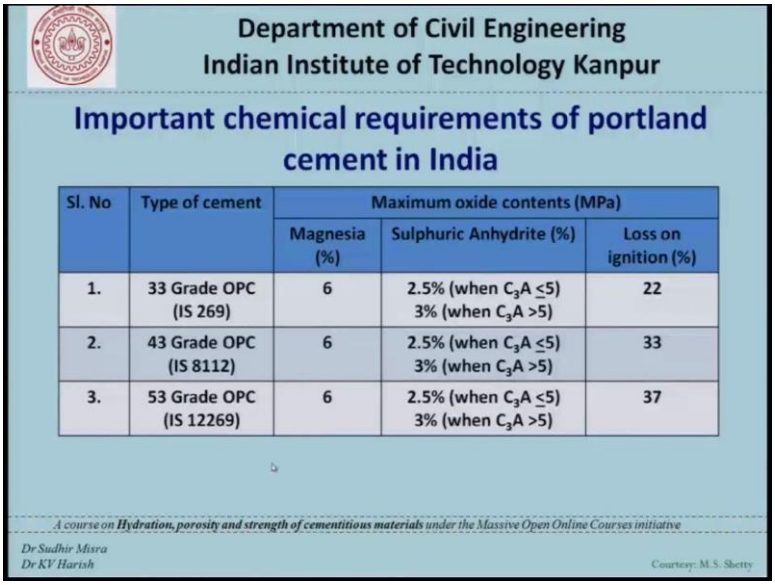

The chemical requirements of Portland cement in India are shown in this table for the 33 grade, 43 grade and 53 grade, the magnesia content should not exceed 6 percent, for all the 3 types of cement sulphuric anhydrite content should not exceed 2.5 percent when Tri-calcium aluminate content is lower than or equal to 5 percent and it should not exceed 3 percent when Tri-calcium aluminate content is greater than 5 percent and the

same is true for all other grades of cement the loss of ignition value for 33 grade cement is 22 percent for 43 grade, it is 33 percent and for 53 grade it is 37 percent.

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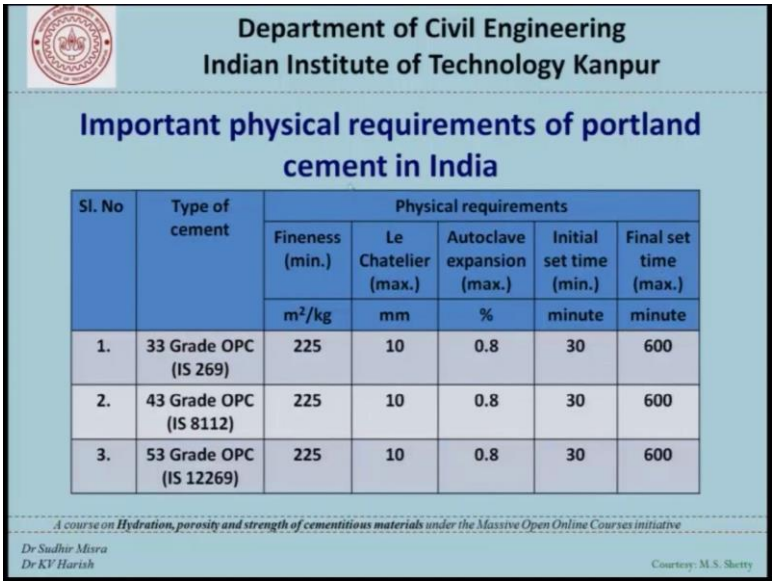

The important physical requirements of Portland cement in India are shown in this table for fineness the minimum specified fineness is 225 metre square per kg for all the 3 type of cements Le Chatelier maximum value expressed in mm is 10 mm for all the 3 types of cement autoclave expansion maximum in percentage is 0.8 percent for all these cements and initial set time remember minimum initial set time is 30 minutes for all the cements and final set time maximum is 600 minutes for all these cements all these values are extremely important.

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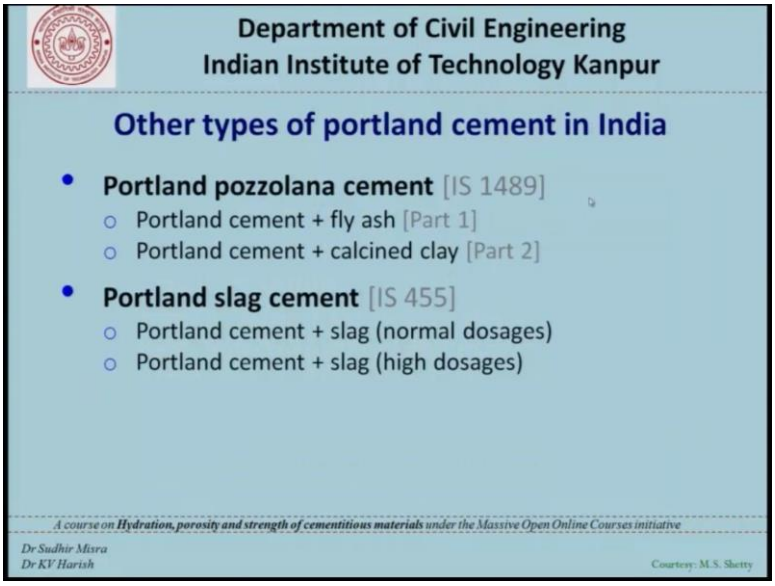

In addition to the different grades of cement available we also have other types of Portland cement namely Portland pozzolona cement specified in IS 1489 and in this, there are again 2 types of cement, 1 is Portland cement with fly ash and Portland cement with calcined clay they are given in port part 1 and part 2 of IS 1489.

The second type of cement that is available is Portland slag cement which is specified in IS 455 and again there are 2 classifications Portland cement plus slag at normal dosages and Portland cement plus slag at higher dosages the explanation of these type of cements and the properties that it can provide are explained at a later stage when we discuss about supplementary cementing materials and pozzolans in cement systems.

Thank you.