**Coastal Engineering**
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**Module - 2**
**Sediment Characteristics and longshore sediment transport**
**Lecture - 1**
**Sediment Characteristics – I**

From today we will get started with essentials of coastal engineering. In fact before getting into this subject, you should have some background on the behavior of ocean waves. What we will try to understand through this subject is how the sand which is lying in the seabed is brought to the surface, and then how it is moving along with the waves and then how it gets deposited. So, this is do not you think that it is very important, because this poses a challenge whether you have a excess sand and excess are depletion of sand supply; both are problems.

So, you have a wide range of case studies dealing with both kinds of problems, and these problems are more or less similar worldwide, but some of the problems are size specific and solutions also become size specific. So, basically there is not much of movement of sand in deep waters; that is d by L greater than 0.5. So, we know that the effect of the surface waves is not felt near the seabed. So, you if at all there is any kind of movement in the deep waters that may be due to some kind of underwater currents, that is all.

The sand in the ocean is moved mostly by ocean waves; tide also act as an agent, because there are some currents which are induced by tides and there are some currents that is in existence due to gradient. All these things contribute in some way or other to the movement of the sand. But what we are really very much interested is and which really dominates in the coastal zone is that which is induced by the ocean waves. So, before we get started with this topic on coastal engineering as I said earlier have a thorough look at basics of wave motion.

I have covered some of these lectures (( )) with the number of worked out examples, go through them, understand the physics behind the phenomena of waves and then get into this topic. So, what we do is there are two things which are interacting; one is the sediments, and another is a wave. The surface shown that is the waves we have covered.

Now, we are going to look at these sediments; naturally when you have a big rock below the seabed it is not going to be moved. So, the simple thing is a size which matters. This everyone of us know, that is common man know, that if it is of a bigger size it will not get moved and as it become smaller and smaller it tends to move.

That is one simple characteristic of sediment; is that all, no. There are some other characteristics of sediments which control the movement of sand and that is supposed to be the fundamental topic which we need to get exposed to. In this class I see that we have people with electrical background or mechanical background, few with naval architectural background and some of you with civil engineering background. For those with civil engineering background, the information which I am going to give may be of very fundamental nature. But even if it is fundamental, it is better we just have a look at it for the benefit of people from other disciplines and I will not be covering all that; I will be covering only that is the parameters that are quite important.

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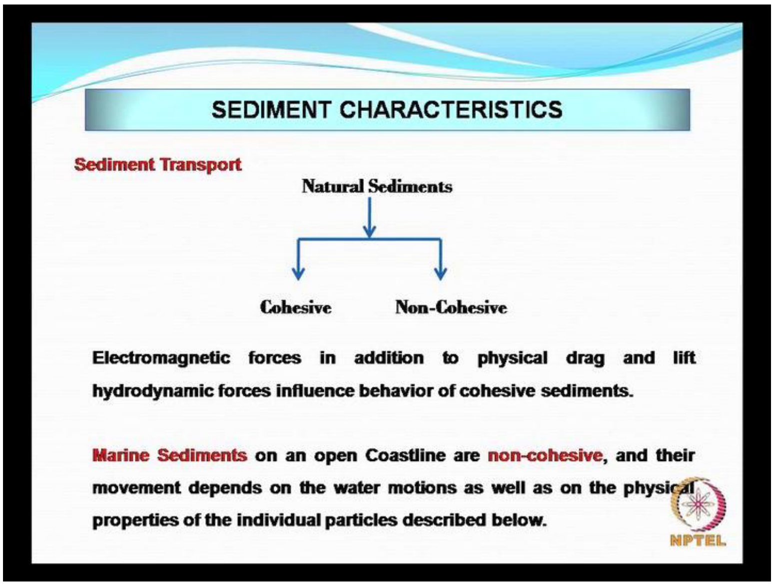


When we talk about sediment characteristics, what are the sediments? Are there any classifications between of the sediments? Yes. Broadly it can be classified as you see the cohesive sediments and you have the non-cohesive sediments. The electromagnetic forces in addition to the physical drag and the lift hydrodynamics forces those influence the behavior of the cohesive sediments. So, when you have a particle you know what are the forces acting on this particle when there is a motion of a fluid, you have basically drag and lift.

What are we dealing with about? We are dealing with marine sediments. Marine sediments on an open coastline are mostly non-cohesive and their movement depends on I simply call it as water motion; why I call it as water motion? Because the motion can be even in normal river or near the estuaries, in the open ocean near the coastal zone, etc and the motion is the water motion. So, if this will depend on the water motions and for a given current velocity, the characteristics of the sediment is important; whether it is small or big for a given thing the speed with which the sediments will move depends on its characteristics; that is its size; that is one of the property. Apart from the size, there are other parameters which are quite relevant when we talk about the motions of the sediments.

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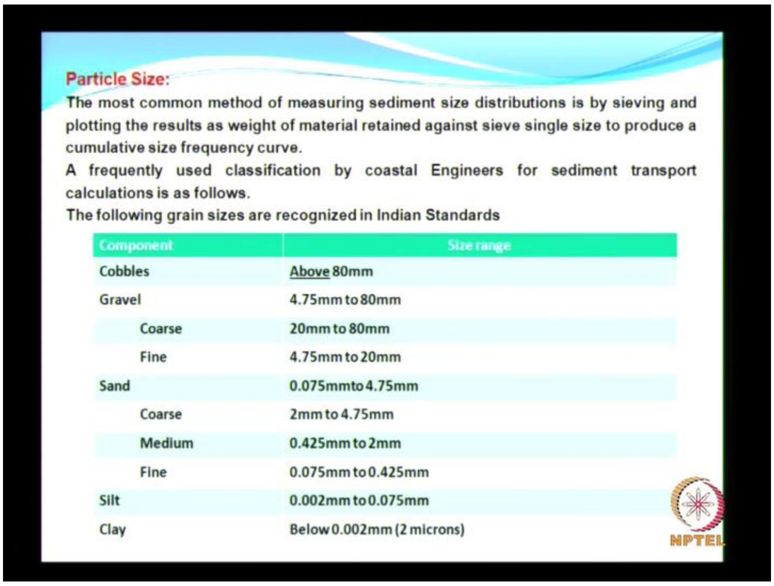


So to begin with, we talk about particle size. The most common method of measuring sediment size distributions is by sieving and plotting the results by weight of material that is retained against a sieve single size to produce a cumulative size frequency which I will explain that later. The simple example is even if you are not civil engineer, I am sure that you would have noticed you have a sieve a bigger one in a construction site particularly when you want to plaster the plaster the wall. So, when you want to plaster the wall you would like to have a smooth surface.

So, naturally you would try to use we get sand from somewhere; we put it on a sieve and this sieve size is as fine as possible so that you will get fine sediments and the coarser sediments are thrown out, so that this fine sediments are used for plastering. So, this is the basic application for sorting out the coarser ones to be removed so that you have a smooth surface. Now there are a number of classifications based on the size of the individual particles. It is named as cobbles, gravels, etc. You have several classification, I mean, British standard, American standard, all these things.

So, you can refer to any standard books on soil mechanics; you get all this information. A frequently used classification by coastal engineers for sediment transport is given here. The following grain sizes are also recognized by our Indian standards. So, one is cobble above 80 millimeters, then gravel 4.75 millimeters to 80 millimeters. So, again gravel can be coarse or fine depending on the variation 20 mm to 80 mm can be coarse, fine can be between when it is ranging between 4.75 and 20 millimeter. Then again in sand you have a say again this gravel also different size of gravels are used for different purpose in construction; I am sure you are aware of all these things.

So, even when you are talking about coastline engineering it has its application in this area. Now, sand is generally found to vary when it is varying between 0.0575 millimeters to 4.75 millimeters, then we term it as sand and under which you have a further classification namely coarse, medium and fine. So this coarse, this classification depends on the range of range of the size of the sediments as given in this slide fine to coarse. Then you have a silt wherein the size varies between 0.002 millimeters to 0.075 millimeters; is that clear, then finally clay which is below 2 micron or 0.002 millimeters. So, this is the broader classification of the sediments that we deal with the marine environment.

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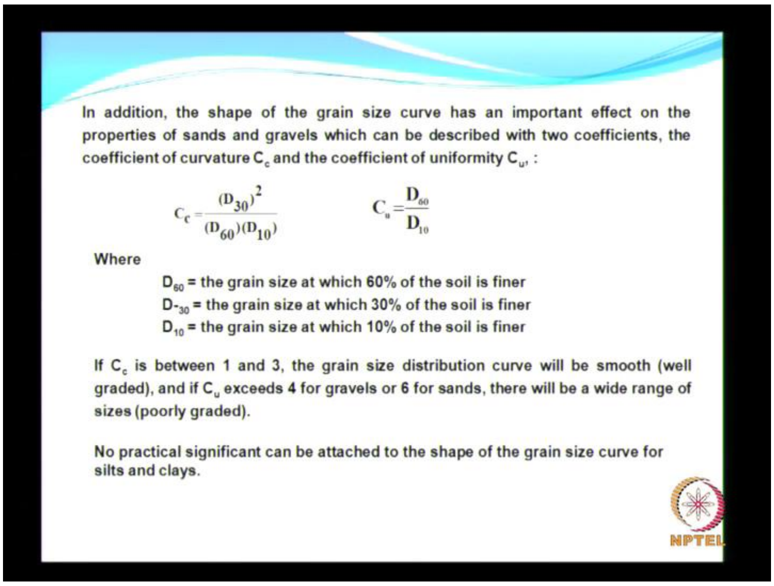


Apart from the size there are other aspects which we need to look into or other properties. So, in addition to the size the shape of the grain size curve, which I will explain later, also has an important effect on the properties of sand and gravel. And this can be very easily defined by two coefficients which are termed as coefficient of curvature given by this expression D suffix 30 to a power 2 divided by the product of D 60 and D 10 and you have the uniform coefficient as the ratio of D 60 by D 10.

What is meant by D 60? D 60 is the grain size at which 60 percent of the soil is finer. What does that convey to us? You take a sample, then you have a sieve and the sieve has a particular size; particular size may be x millimeter. Then you put the sample which has arrived the site through this sieve which has x millimeters. Then some of the sand will go down through the sieve. So, here you have and some of the sand will be retained. So, you know what is the percentage of weight of this sand which is retained in the sieve and what is the percentage of sand which has gone through the sieve which means which is finer than which is finer. So, much of percentage is finer. So, much of percentage is coarser.

So, this says that D 60 the grain size at which 60 percent of the soil is finer. And similarly you have D 30 D 50 and D 10; it is very common to use D 50. So, now you if the C C that is the coefficient of curvature is ranging between 1 and 3, the grain size distribution curve will be smooth. When I say grain size distribution will be smooth, the grain size distribution will be something like this; very soon I will show you. When I say the we have a particular sample the sand of marina beach, suppose in case I say the coefficient of curvature for marina beach sand is between 1 and 3; that means this sand near marina beach is well graded is well graded and the distribution curvature is quite smooth.

There is not much of variation in the size; whereas if C u exceeds 4 for gravel and 6 for sand, then there will be a wide range of variation and then we say it is poorly graded. So, these parameters will vary from location to location you understand. So, if it is a beach which has fine sand, then all the sand will be going up and all the sand will be coming down; do you understand. But if it is coarser sand, you will have a complicated behavior of the motion of the sand near the beach; understand. So, those aspects we will see later. No practical significant can be attached to the shape of the grain size for silts and clays. We are not going to cover anything much about silt and clay in this subject. We will be mostly talking about sand because that is the one which creates lot of problems and also benefits; the beach is found by sand.

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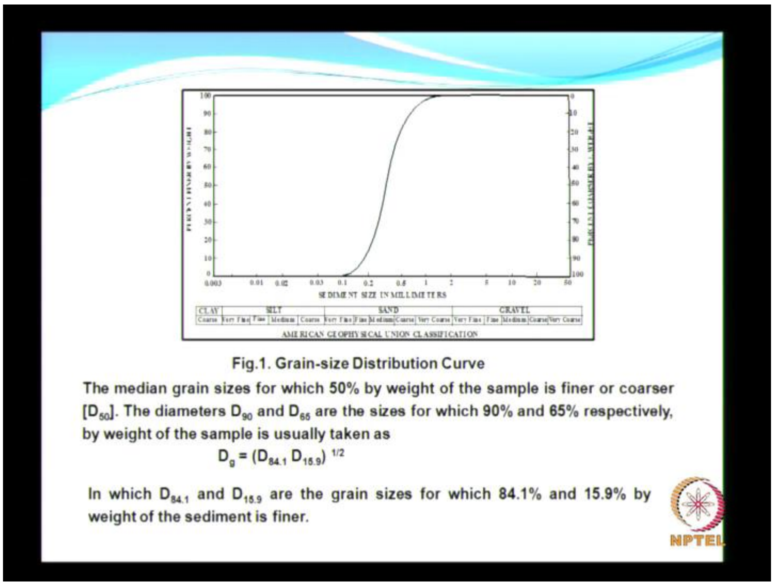


Fig.1. Grain-size Distribution Curve

The median grain sizes for which 50% by weight of the sample is finer or coarser [$D_{50}$]. The diameters $D_{90}$ and $D_{65}$ are the sizes for which 90% and 65% respectively, by weight of the sample is usually taken as

$$D_g = (D_{84.1} D_{15.9})^{1/2}$$

In which $D_{84.1}$ and $D_{15.9}$ are the grain sizes for which 84.1% and 15.9% by weight of the sediment is finer.

So, this is the grain size distribution curve; what that does that give? So, on the right side you see that it is percentage finer by weight and on the left side you see percentage coarser by weight. On the x-axis you see the size of the sediments in millimeter. So, the curve can be as smooth as possible like this not much of range not much range, but it can also have a wider range. So, this depends on the sample and, I mean, the location from where you have got the sample. If you want to find out the characteristics of the sediment you have to perform the sieve analysis, obtain this curve and then get all the other kinds of information like coefficient of curvature, consistency index, etc, etc; is that clear

So on this, if you look at this scale here this scale gives; so, this is less than this value it is clay and between this and this; that is this is a sediment size and now if the sediment size is ranging between this and this much, then we say it silt and again you have a further classification; this axis this classification is from this axis. So if you look at this picture, suppose if I want 20 percent finer; 20 percent finer means around the grain size will be 0.3. Naturally when I say 20 percent finer it will be 80 percent coarser; is that clear

So, this kind of a curve representation of the grain size is extremely important for costal engineering practice and even for our general civil engineering structures. The median grain says normally we use D 50; D 50 is 50 percent of weight of the sample which is finer or coarser. So, there are other diameters like a D 90, D 65 or and so we also have what is meant by d g; d g is given by this kind of variable, I mean this kind of parameter as shown here. So, all these things are used in fundamental soil mechanics or coastal engineering practice. So, some of these finds its application.

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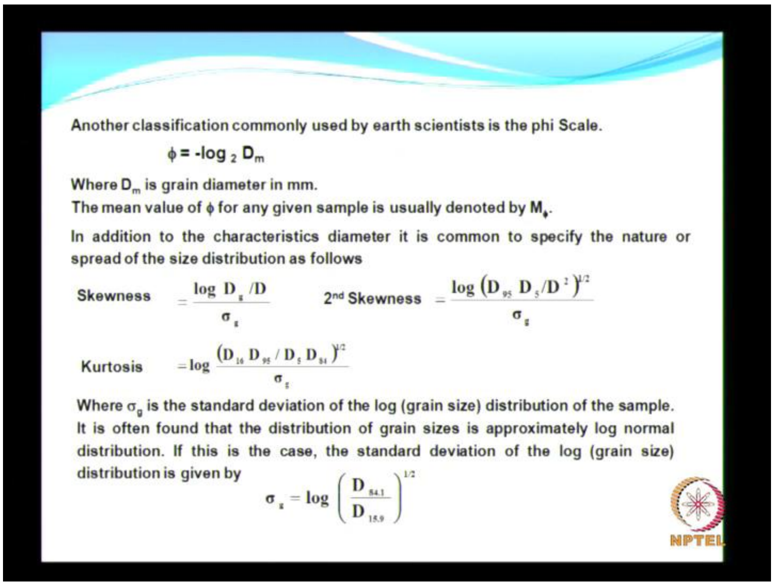


There are other classifications; one of the classification which is usually used by the earth scientist is the phi scale. So, D m is the grain size or the medium grain size in millimeter. So, that phi will be give as in terms of log 2 into D m and the mean value of phi is given by m suffix phi. And in addition to the grain sizes which are very commonly used, there are other statistical measures to describe the characteristics of the sediment which are given here. For example, you have the Skewness, second Skewness, kurtosis, etc and here in kurtosis all these variables are known to us except that sigma g is a standard deviation of the log distribution of the sample and this sigma g is obtained by this expression as you can see here.

So, these are all only just different kinds of representation of the characteristics like Skewness it gives the statistical measure, how it is skewed, etc. Sometimes your investigation or the designed purpose you may not require all this information; you may require only the grain size, that is the d g. Later you will see when you are calculating your sediment transport, the one of the main parameter you will be dealing with only the grain size. Even if you are not using this frequently it is better that knowledge on this existence of such kind of parameters if you have it is good. Is that clear; any doubts, any clarifications.

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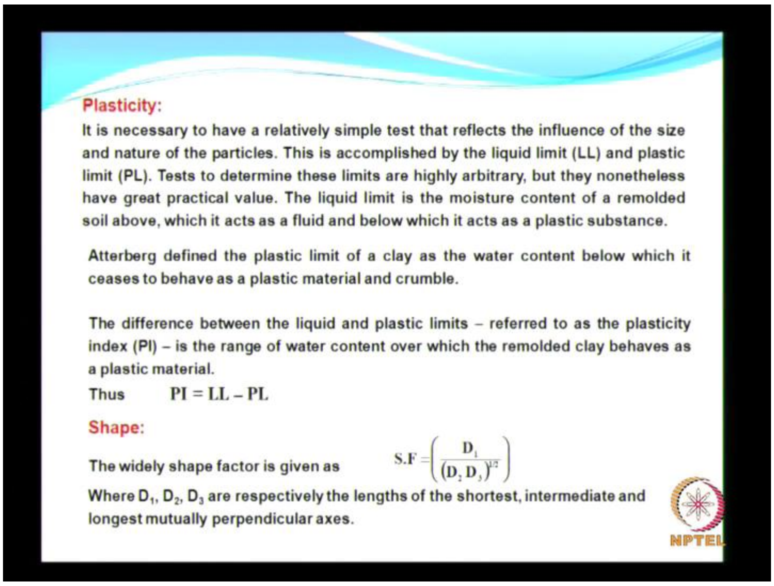


The next characteristic is the plasticity. It is very essential and in fact it is absolutely necessary to have a relatively simple test that reflects the influence of the size and nature of the particles. The civil engineering students, I am sure you would not have got your degree without performing this experiment. This is one of the basic experiments for the civil engineers obtaining the liquid limit and plastic limit. So, if you want to find out the behavior of or the influence of size and nature of particles, this can be accomplished by determining the liquid limit which is given as LL here and the plastic limit of a given soil sample.

So the liquid limit, what exactly is the liquid limit? Liquid limit is the moisture content of a remolded soil above which it acts as a fluid and which normally acts as a fold fluid when it is remolded and below which it acts as a classic plastic substance. So, that definition of this is available in the complete description of this liquid limits and plastic limit; you can get in any standard civil engineering book, I mean soil mechanics book. Atterberg defined the plastic limit of clay as the water content which it seizes to behave as a plastic material and crumble. So, the limit beyond which when you try to do like this it will crumble also.

So, if that status reaches then we call it as a plastic limit. So, we have for once you estimate the liquid limit and the plastic limit, the difference between these two limits referred to as plasticity index. So, what is plasticity index? Plasticity index is the range of water content over which the remolded clay starts behaving as a plastic material. So, thus I will say plasticity index is the difference between the liquid limit and plastic limit. Thus the shape of the grains, does that have any effect? Because you know how small is the sand but still the sand has a shape and will this shape has any effect on its movement, etc.

The widely adopted shape factor is given as D 1 divided by the square root of product of D 2 and D 3. What are these D 1, D 2 and D 3? They are respectively the lengths of the shortest intermediate and longest mutually perpendicular axis. All though you have a variety of civil engineering books which give the details of the sediment characteristics, as far as that sediment characteristics for coastal engineering practice is concerned I would suggest the book by Herbich.

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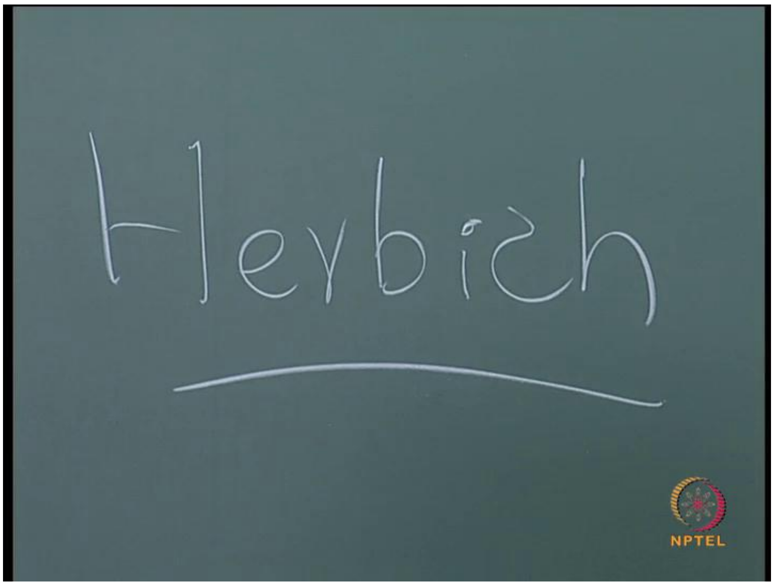


You can refer to as handbook of coastal engineering and other kinds. He has written a few books and the reference of this book is given under the references of my lecture material which we will see later. So, if you want to have more information I would suggest apart from the other books, this would be a very good book which you can have a look at it.

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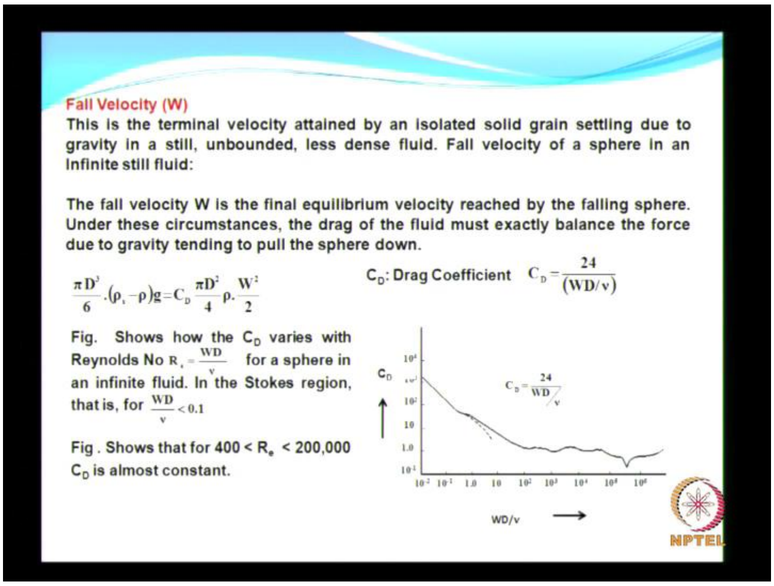


Then comes fall velocity; what is fall velocity? You take a beaker of water; you put a small stone, what happens to that? It goes down; does it have any velocity? It goes down with a velocity. If you have a bigger stone it goes with higher velocity, but we are not talking about such big stones; we are talking about the fall velocity of sediments in suspension. The sediments will slowly settle down and naturally now when I said stone and sand, we are talking about the size; when we talk about the size we are talking about the weight of the sediments.

So, we clearly know that the fall velocity is going to be dependent directly on the weight of the particles. So, what is meant by fall velocity? It is the terminal velocity attained by an isolated solid grain settling due to gravity in still, unbounded, less dense fluid. Because you want the sand to go into the fluid; it will settle down, right. So again I repeat, it is the terminal velocity attained by a grain settling due to gravity. So, when settling due to gravity means there should be some kind of resistance also offered. If there is no resistance the whole thing will go down; right.

So, the fall velocity or the final equilibrium velocity let us consider a sphere a sediments particle as a sphere. Now under this circumstances that is we are trying to find out the fall velocity of a falling sphere. Under these circumstances drag of the fluid must exactly balance the force due to gravity that is trying to pull down the sphere. So, when you equate these two this is the drag force and this is the force due to falling sphere. So, this is nothing but because it is submerged; right. So, you have the density of the sand and density of the fluid. So, when you try to equate these two which is the one which is going to dictate? Your coefficient of drag is also going to control the speed with which the sand is going to move down which is nothing but your fall velocity.

So, this figure shows how the coefficient of drag will vary with the Reynolds number. You brush up the fundamentals when you talk about coefficient of drag; naturally it is associated with Reynolds number and Reynolds number is nothing but W D divided by nu where nu is the kinematic viscosity and we have given also the limit for the Reynolds number. Now if you look at this picture, this shows how the drag coefficient is going to vary with respect to the Reynolds number. So in this range, somewhere in this range you see that the C D is more or less a constant. For very low Reynolds number you see that the coefficient of drag decreases.

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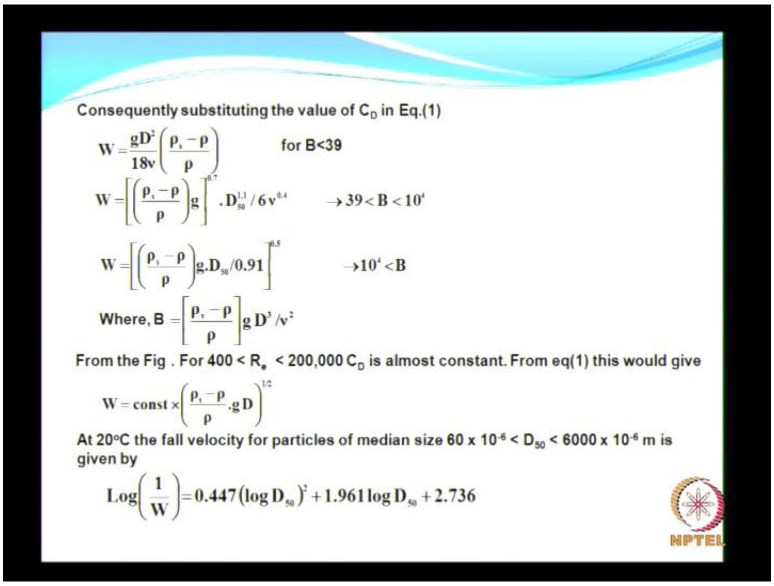


And it is possible that from this you can always get coefficient of drag as equal to 24 divided by your Reynolds number and when you re-derive all these things, you will have a equations for the variable B which is given as shown here; if B is defined as shown here for the value of B less than 39, the fall velocity can be expressed as by this equation and the same fall velocity can be expressed by this equation if B is of this range and this can be when B is less than so much, I mean B is greater 10 to the power 4. So, the fundamental thing is equating the two forces; one is the drag force that is going to be exerted and the weight with which the whole thing is coming down.

When we equate this you get what is called as the fall velocity, but we have a clear distinction or this variation is going to depend on the value of this parameter. So, this is what the literature says and this I have already told you that for this range the drag coefficient is almost constant. So from equation one, we can say that W is a constant into this one. So, there are other types representation as given in the bottom equation in terms of log where in order to determine the fall velocity what you need is only the grain size. So, you have a sample and you want to know its fall velocity. Perform the sieve analysis, obtain the D 50 which we have already seen, substitute in this expression and get your fall velocity.

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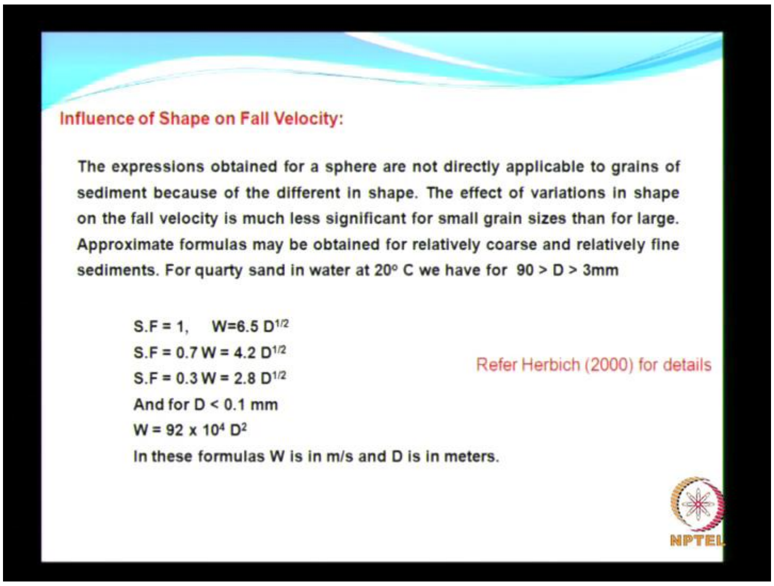


Do we have any kind of influence of the shape on the fall velocity? Why this fall velocity is important? In the open ocean when the sediment is coming up from somewhere, it is in motion. If it is heavier naturally it will settle down fast; if it is not heavy it will be floating.

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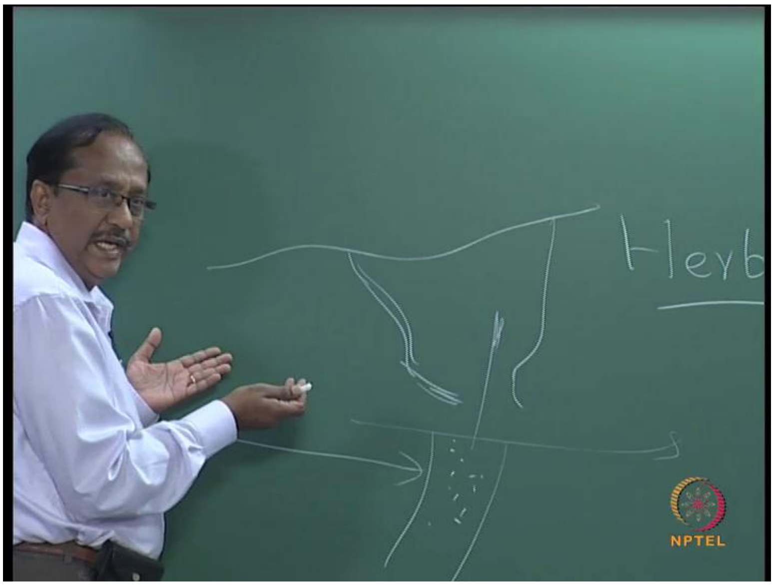


So for example, if you have a harbor, this is simple thing, you see that this is the harbor formed by artificial break waters; artificial harbor formed by break waters and the sand is moving, for example. And suppose if this area is mostly of coarse sand which has been lifted and which is in motion, what will happen? The coarse sand might if the fall velocity is going to be high it will simply settle in the approach channel but if it is very fine what will happen? The sand will either go straight or may be also entering into the harbor.

So, in this way you see if you have the coarser sand, you might land up in trouble and there are so many other examples where coarser sand may be of benefit. Suppose for example, if you have constructed this or you have some other area where you want the sand to deposit; for instance you want to develop a beach, there what do you want? You want the sand to deposit and you do not want the sand to move away. So, you would like to have coarser sand; you would like to develop such areas and could be developed in areas characterized by coarse sediments. So, whether it is fine or coarse both have advantages both have disadvantages, but it is extremely important to know the characteristics of the sediments.

Now influence on the shape on fall velocity, the expressions for a sphere are not directly applicable to grains of sediments because of the difference in shape. What we had assumed in the case of fall velocity? Its only an assumption because it is very easy to arrive at an expression; that is it has been considered a sphere has been considered but naturally the grains occurring in nature may not be spherical at all. So, the effect of variations in shape of fall velocity is much less significant for smaller size grains compared to the large; this is obvious but when we are talking about coarse sediments, the reason why we need to talk about the coarse sediments is I just now explained.

So, in this case approximate formulas have been derived or it is all available in literature for relatively coarse and relatively fine sediments. So for example, you apply a shear factor of 1. If shear factor is approximately 1, then you see that W is equal to 6.5 into the square root of D and a shear factor is equal to if you assume shear factor as 0.7, then the fall velocity is 4.2 times the square root of D and then shear factor when equal to 0.3, then the shear factor is equal to 2.8 to square root of D. For D is less than 0.1 millimeter then you have a direct relationship for W. In this formulas now W is in meters per second and D is in meters, but for all the details you can also verify the book of Herbich.

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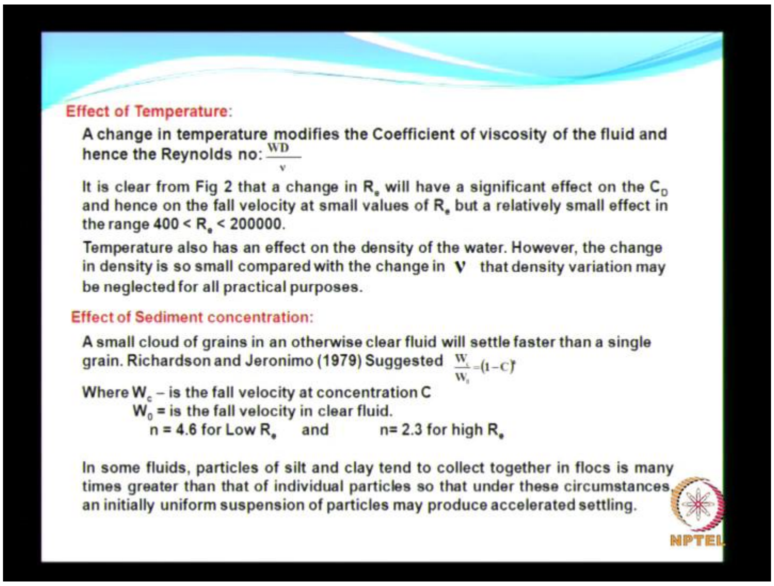


So, although we have some guidelines of on the shape very often we neglect because it is extremely difficult to adopt the shear factor in the case of our coastal engineering practice, but we need to know that there is a kind of a parameter which might have some influence. But although the influence is negligible still we should have this in mind. Now effect of temperature we are dealing with. So, already saw that the variation of coefficient of drag which controls or which in someway or other it is related to the fall velocity. And coefficient of drag naturally it is a dependent on the Reynolds number and Reynolds number has the kinematic viscosity which is going to be a function of temperature and that is where the effect of temperature comes into picture.

So, earlier when we saw the variation of coefficient of a drag here in this picture, you see that you have the change in R e; I mean the Reynolds number will have significant effect on the C D at least for smaller range of Reynolds number and that is where your temperature comes into picture. So, the effect of temperature or the temperature as controlling effect on the fall velocity for smaller Reynolds number; naturally after Reynolds number is greater than 400 you do not have much of effect of the temperature.

Then comes the effect of sediment concentration; what is sediment concentration? A small cloud of grains or in other words in a very clear liquid will settle faster than a small single grain; that is clear. So, it was Richardson and Jeronimo who suggested a formula that gives the fall velocity of sediments with concentration C as you can see here and W naught is the fall velocity in clear liquid. One is with concentration, another is with clear liquid and this is what we can use and this to the power n is approximately equal to 4.6 for low Reynolds number and n equal to 2.3 for higher Reynolds number.

So, this is the kind of formula you will have. So, if the concentration is more the fall velocity will be more. So, in some fluids particles of silt and clay tend together in flocs and are many times greater than individual particles, so that under such circumstances an initially uniform suspension may produce accelerated settling. So, that is this is nothing but the effect of flocculation; you would ask at least the civil engineer must have heard of flocculation.

So, if you have this as your concentration the sediments will cling on to each other and then there is a possibility for them to settle down quicker; if you want to have the settling fast. Then I think I will stop here and then we will move onto any questions I will stop here; are there any other questions or doubts, clarifications. Since these are all fundamentals and mostly for the civil engineers it is too fundamental, I suggest the students from other discipline have a clear look into all these parameters and also refer to some of the books I have suggested at the end of the chapter; at the end of my presentation on this topic. So, I hope there is no question.