Soil and Water Conservation Engineering
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Lecture - 51
Formation of Sand Dunes

Hello friends welcome to this week 11 and lecture 4 of this course of Soil and Water Conservation and Engineering. And we were studying in this week 11 about the wind erosion and different control measures ok. So, in the in this lecture will be understanding the process and different kinds of sand dunes and formation of sand dunes.

So, like so far now we have covered we have seen we have studied the 4 lectures. We have studied what is wind erosion? What are the different factors that are associated or that can triggers the wind erosion? And different types of sand movements, initiation detachment, initiation then transport and deportation, different types of soil particle movement depending on their size and grade so that we have seen.

We have also seen the different different kind of wind erosion control measures to reduce the effect of wind speed. So, we have seen the some measures to reduce the velocity of the wind and some measures to make soil surface more make soil surface more resistant to the wind erosion.

And then we have seen the design of some structure which can reduce the wind speed. So, for example wind break design of wind break we have seen and we have also seen the design of shelter belt ok.

So, in this lecture so today we will be understanding the sand dunes, their formation and there different different types of sand dunes sand dunes and how they formed? So, let us start this lecture.

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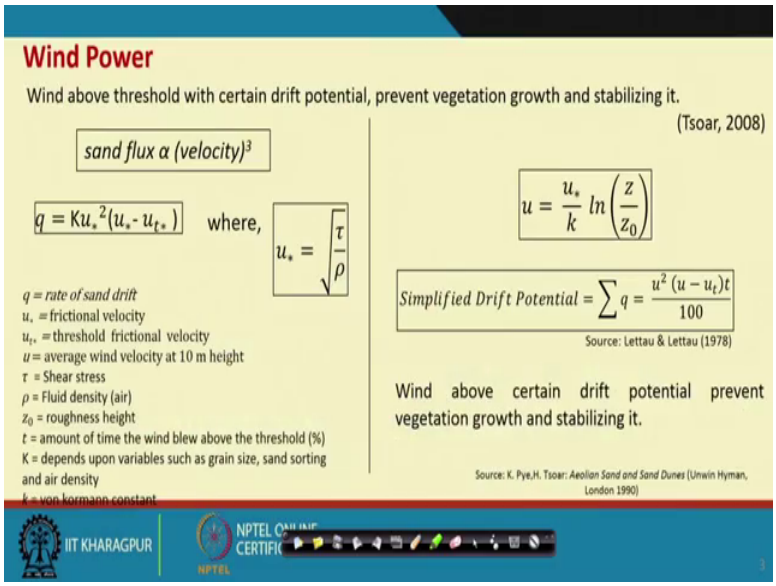

So, before that this thing also we already discussed that to this initiation of soil particle from this initiation of this wind erosion, when it start. So, the wind velocity should be a actually greater than threshold velocity, some minimum threshold velocity. But, we can see not only the threshold velocity that defines the amount of sand transport, but it the wind should be above some threshold, wind should be above some threshold with some with some certain drift potential. So, that kind of wind will prevent vegetation growth and we will prevent the stabilization or the (Refer Time: 02:42) ok.

So, the wind should be above the threshold with some certain drift potential that prevents vegetation growth and stabilizing it. So, we know that this quantity of sand flux or quantity of sand moved is actually directly proportional to the velocity cube ok. So, we can approximate that quantity by this equation so, here q is a rate of sand drift in one particular direction.

So, q is equal to some constant K multiplied by u stars square into difference between the threshold and the frictional velocity. So, here u star represent the frictional velocity that is not the actual velocity. So, it is actual frictional velocity u star and ut star is the threshold frictional velocity and the difference between them when multiplied with the square of frictional velocity and with some constant and the constant that depends on the soil parameters like grain size sand sorting and density of air.

So, related to the surface and surface condition so, we can get the rate of sand drift ok. So, here this frictional velocity is we know that frictional velocity is actually the square root of shear stress divided by density of the fluid ok. So, here q is the rate of sand drift, u star is the frictional velocity u t star is equal to is actually the threshold frictional velocity.

And this rho is a fluid density, and k is any constant that depends on variable such as grain size and sand sorting and air density and talks a shear stress ok. So, this we can approximate this we can approximate a drift sand drift in one particular direction by this equation which is given by Lettau which is given by Lettau and Lettau ok.

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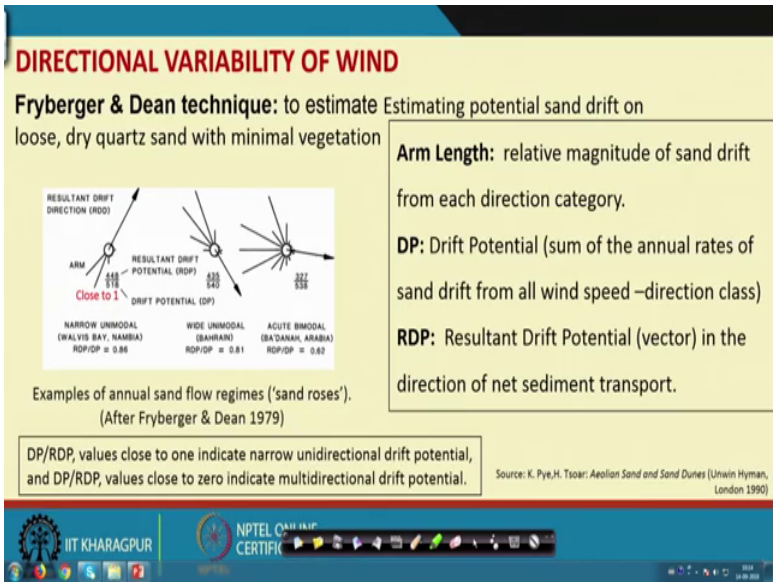

So, we can approximate the sand drift by this equation which is given by Lettau 1978 ok. So, here we can say that the quantity of sand drift in one particular direction is given by u square multiplied by u minus u t divided by 100. So, here u is the wind velocity which is measured at a 10 meter height, let us say 10 meter height and which is given by this equation, u can be calculated like this.

Frictional velocity divided by k in to natural log of ratio between Z and Z 0. So, Z is any height, Z 0 is a roughness height and here t here is actually the amount of time the wind is above the threshold so, percentage it is actually percentage. So, percentage amount of time during with the wind is above the threshold ok. So, as we said this wind above this drift potential can prevent the vegetation growth and can and stabilizing it ok.

So, this is the this equation gives us the simple drift potential it is actually sum of all drift potential in all direction so, this will be needing in the subsequent slide. So, we will move to the next slide ok so this directional variability of wind if you want to estimate, so this was technique was given by Fryberger and Dean technique.

So, this technique can be used to estimate the potential sand drift on loose dry sand and minimal vegetation ok. So, these are the assumption loose and dry and quartz sand with minimal vegetation ok. So, what we can do actually? So, if we have a wind data at one particular height. So, we can find the frequency of the sand drift in particular direction is specifically 16 direction, 16 identical sorry 16 directions ok.

So, and we can plot it in the form of this diagram. So, this diagram is known as the annual sand flow regimes or also known as these are the sand roses ok. So, here this individual arrow this individual arm that represents the relative magnitudes of sand drift from each direction category ok. So, we need to calculate the sand drift in each direction given by the equation q ok, so that represent the relative magnitude of sand drift in that particular direction category ok. So, accordingly that we will plot all the arms and next is we need to calculate the drift potential ok.

So, drift potential is actually sum of annual rates of sand drift from all winds alls from all wind speed direction ok. So, if you sum all this annual rates of sand drift from all direction we will get drift potential. So, it is a sum of annual rate of sand drift from all wind speed direction ok.

Then the result and drift we need to calculate result and drift potential ok. So, this resultant drift potentials are actually the representative vectors that represent the net sediment transport, net resultant sediment transport ok. Suppose these are all the winds vector wind vector in different direction and this is the vector represent the net sediment transport ok.

So, this figure show us the different types of different locations resultant drift directions ok. So, this is the resultant direction here, here the resultant direction this is a resultant direction. And this ratio is the ratio of between resultant drift potential divided by drift potential so, this is ratio of RDP by DP this is also known as the directional variability index ok.

So let us let see here so, in this case in the first case there are very less variability. So, the winds are mostly in this direction and this direction and the in other direction the winds are very less in the first case I am talking about. So, there are very less winds or drift there are very less amount of sand drift in other direction there are two more prominent direction and this is resultant direction.

So, if you take a ratio of this RDP by DP. So, this ratio is actually is coming as 0.86 which is close to 1, so what it means that it is a unidirectional or narrow unimodal flow ok. So, flow is mostly in one direction ok, similarly here the flow is spread in different direction drifts are there in different direction, so resultant and resultant in this direction.

So, actually this ratio RDP by DP it tells us about the direction in which sand drift is taking place ok. So, this DP by RDP values, if they are close to 1 it indicates that narrow unidirectional drift potential and if they are close to 0; if they are close to 0 then it indicates multidirectional drift potentials. So, here we have a multidirectional drift potential so, in the first case it was unidirectional, it is multi directional here ok.

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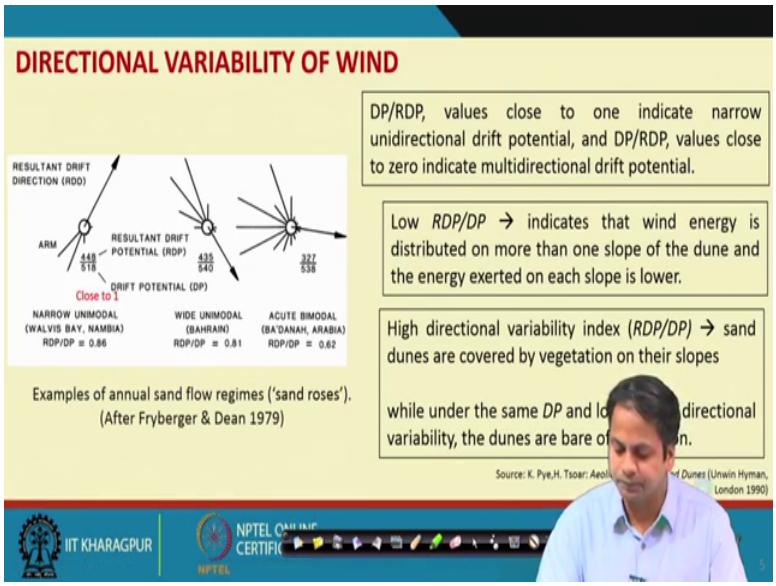

So, as I said this drift potential this index out directional variability that is DP by RDP directional variability index. If their values are close to 1; it means that the flow is they have it indicates the narrow unidirectional drift potential. And if this ratio is close to 0, it is it indicates the possibility of multidirectional drift potential ok so, let see one example here.

So, if the low if the this ratio RDP by DP if it is low ok. If the ratio of RDP by DP if it is low that then it will indicates the wind energy is disturbed distributed on more than one slope of the dune and the energy exerted on each slope is lower ok. So, what it means? So, if the this RDP by DP is less, it means so the wind energy is only not evenly it wind energy is distributed in different directions.

So, the there is a drift in all in different directions. So, it indicates that the wind energy is distributed on more than one slope of the dune and energy exerted on each slope on each slope is lower ok. So, that results in to the lower RDP by DP ratio, similarly high directional variability index ok. So, if this index values are high it means sand dunes are covered by vegetations on their slopes.

So, this vegetation they actually reduce the erosion of wind they can reduce the erosion. So, the high this ratio RDP by DP indicates the sand dunes are covered by vegetation. So, if this drift potentially same it means quantity of sand some of sand drift in all particular direction if it is remains same. And still we get this low rate direction of variability, then it indicates the dunes are dunes are bare of vegetation so, there is minimal vegetation on that surface ok.

So, with that using this technique we can find out the directional variability of sand drift ok. And we can decide whether the vegetation in the current form then current nature of soil surface over that region ok.

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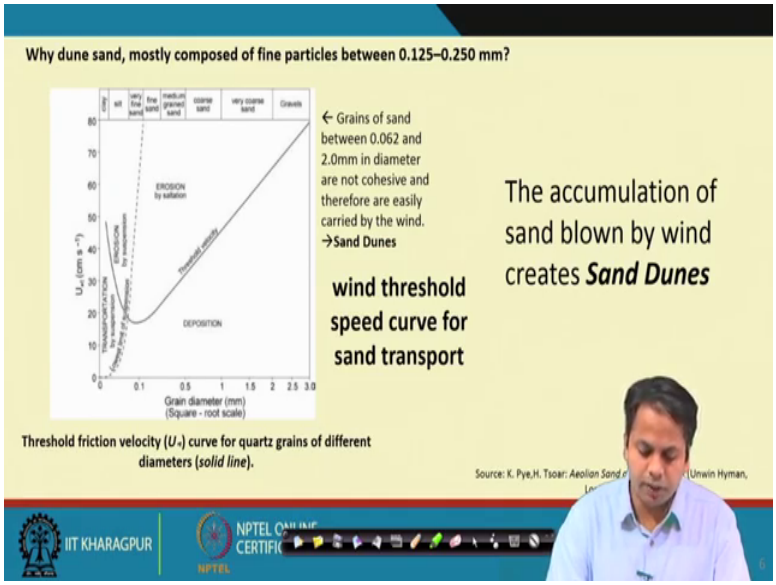

Now, this figures show this actually a curve which represent the wind threshold speed curve for sand transport ok. So, if we see here so on the x axis we have grains; grain diameter of different size square route scale. And on the y axis we have frictional velocity for quartz grains of different diameters ok.

So, we can see here if thus size of the grain is let say is in the range of 0.062 if it is range of 0.062 let us around 2 mm diameter. So, most of the erosion is done by a wind erosion is done by soil erosion process. So, this and this is a threshold velocity above which the detachment or initiation start this is the threshold velocity, frictional threshold velocity ok.

So, grains of between 0.062 and 2 mm in diameter there actually not very much cohesive and they can be easily eroded or they can be easily carried by the wind ok and they can form they can responsible in to sand dunes. But, if you see the size is lesser than if the grain size is lesser than this value like clay or silt or very fine sand. Then in that case most of the erosion process is done by suspension movement ok so, this is a lowest limit of suspension ok.

So, here the mostly suspension is taking place or suspension is acting on very final grains soil particle. And siltation is acting on grain of size between 0.062 and 2 mm diameter and that are responsible for omission of sand dunes ok so, the accumulation of this sand blown by the wind it create the sand dune ok.

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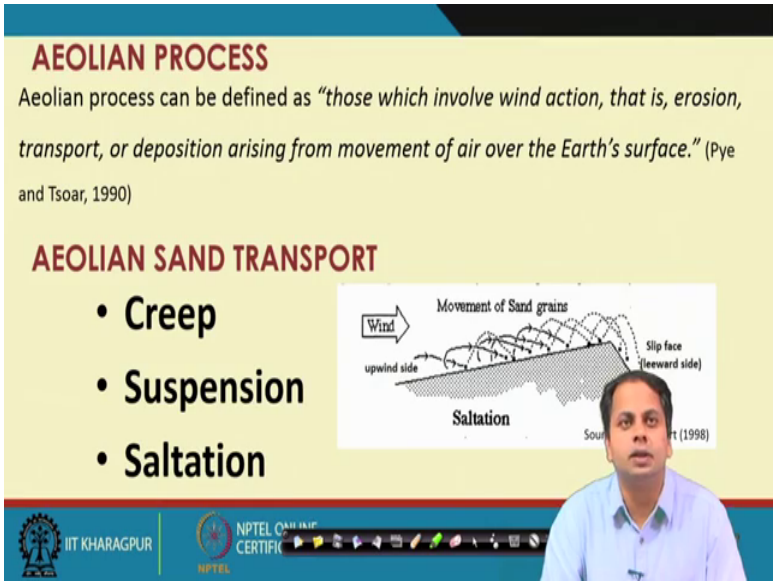

Now, let us see the Aeolian process ok. So, Aeolian process Aeolian is a word a Greek word which is related to the wind, so Aeolian process it can be defined as those which involve wind action that wind action that is erosion transported transport or deposition arising from movement of air over the earth surface ok.

So, this Aeolian process or transport of wind transport of soil by wind. Aeolian process can be defined as those which involve wind action that is the erosion, transport and deposition arising from the movement of air above the over the earth surface. And we have seen the different mechanism by which sand particle or sand grains or transfer from one place to another place.

So, the moment can be by creep by rolling over the surface. Suspension final particles suspended in the air and the soiltation the vibration or jumping and bouncing nature of the bouncing motion of the sand ok. So, this figure represent the movement of sand grains, so this is up wind side and this is slip face or leeward side ok. So, sand is being transported from one place to here this is also known as the windward side or source side ok. So, this will be seeing the next slides ok.

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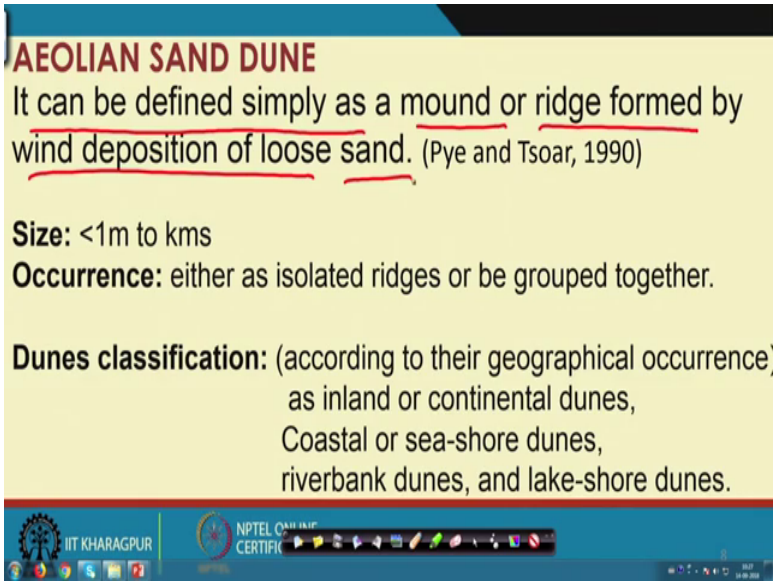

Now, Aeolian sand dune can be defined the sand dune can be defined simply as a mount or rich that are formed by wind deposition on loose sand. So, it can be defined simply as a mound or ridge that are formed by wind deposition of loose sand ok.

So, the their size can be the size of sand dune can be of variable size they can be either around 1 meter or can be spread across several kilometers as well ok. They mainly occur either as a isolated ridges or they can be grouped together ok.

This and the classification and sand dunes are classified according to their geographical occurrences either as a inland dunes or continental dunes or coastal or sea shore dunes or in case of river bank we can call it as riverbank dune or lake shore dunes ok. So, these are the classification based on their geographical location and there occurrence or that region ok.

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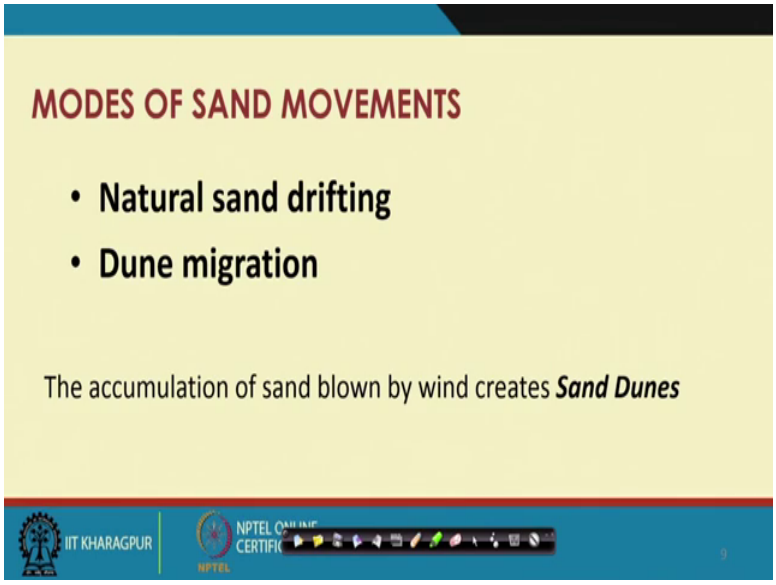

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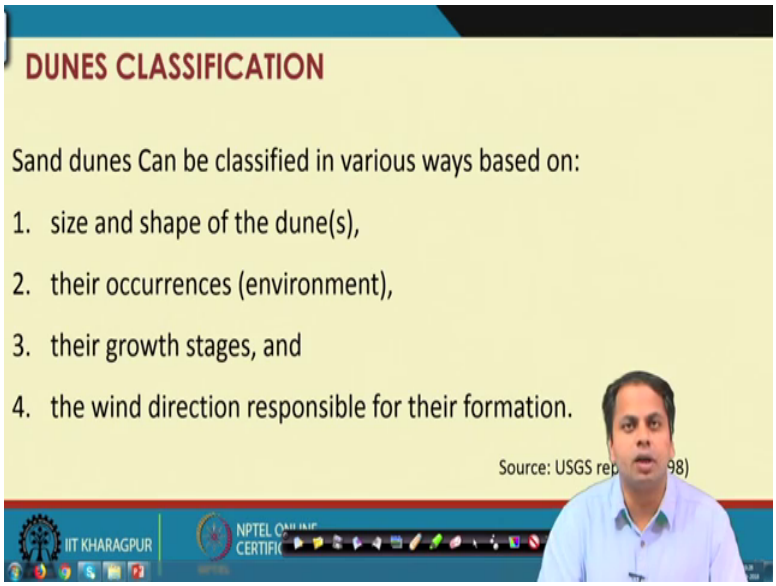

And the modes of sand movements can be either by natural sand drifting or by dune migration. So, dunes we have seen the it can be classified they can be also classified based on different ways like size and shape of the dunes, their occurrence. And the environmental condition as I said the inland sea shore coastal dunes or river bank dune there their growth stage ok; their growth stage depending on the maturity level, then the wind direction which is responsible for their formations.

So, these are the different ways by which we can classify or we can name of particular dune. So, mostly based on the size their occurrence, the environmental and environment in which their present, their growth stage and wind direction which is responsible for their formation ok.

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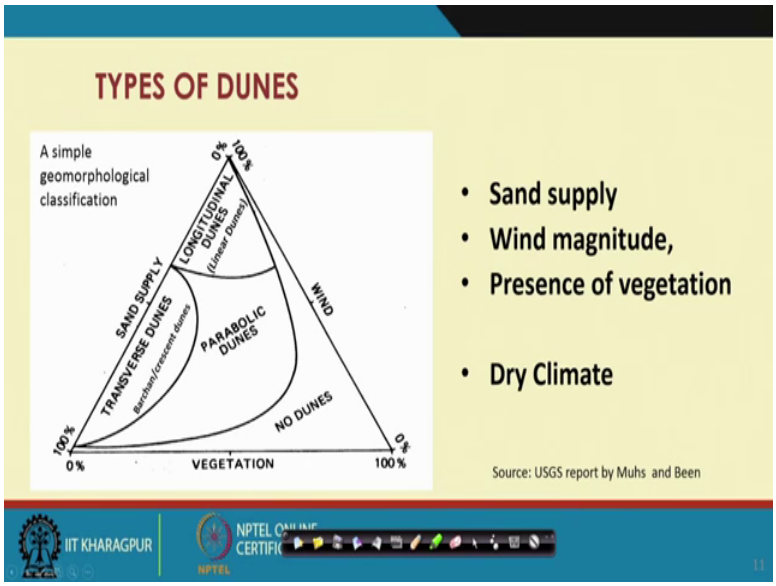

So, this is very simplistic way to represent types of dune. This is a very simple geogram geomorphologic classification. So, dunes are mostly form in the presence of let us say when there is enough availability of sand, sand supply wind magnitude, presence of vegetation and presence of dry climate. So, this is a very simple geomorphologic classification of dunes ok.

So, broadly they can be classified such as transverse dune or barchans crescent dune, and longitudinal dunes and parabolic dunes ok. So, depending on the percentage availability of sand supply, then wind magnitude over that region and the presence of vegetation they can be called as either transverse dunes or barchans or crescent dunes. So, we will be looking this will be understanding this dunes one by one in the subsequence slides. They can be also name as longitude name depending on the variability of different parameters ok.

So, let us say if for example of transfers dunes so, we have very less vegetation and sand supplies around abundance sand supplies there. Whereas, in parabolic dunes we have enough or sufficient vegetation and the action of wind we have earn thus winds are also kind of abundant ok. So, these are the different simple geomorphological classification which can be used to define or to categorize the dunes. So, we will be looking this classification or each category one by one in the next slides.

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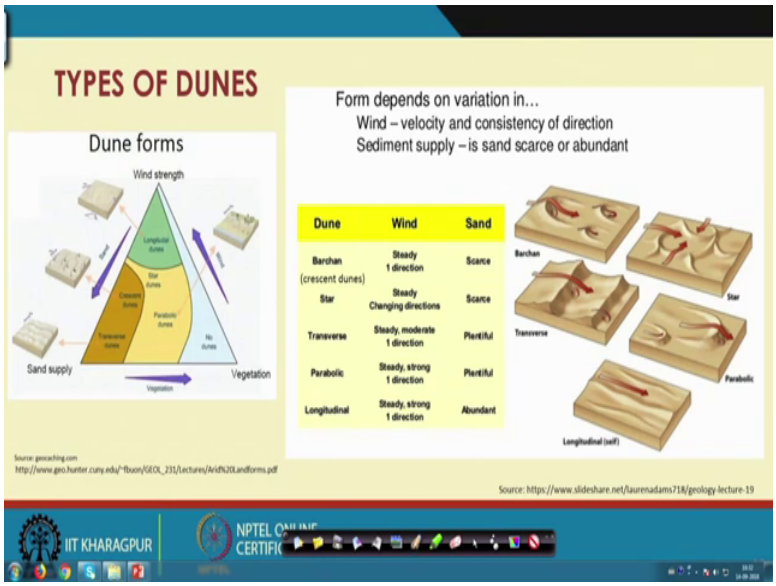

So, this is again the same image the forms of dunes. So, here actually is same like here the frequency in this direction vegetation is increasing, here the wind strength is increasing here sand availability is increasing ok. So, there are different type such as longitudinal dunes when the winds when the winds are wind speed is more wind sand is more vegetation is less. So, this is linear or longitudinal dunes.

So, in case of barchan in case of barchan we have the scars and supply and the vegetation is also less. Then the then comes the transverse dunes when the sand suppliers enough trans sand supplies enough, but the vegetation is less. And winds are also kind of less here kind of less or moderate in moderate form. Then comes the star dunes which have study and direction for changing here. So, here the wind directions are subjected to change here in this region ok.

So, we are so in that reason we get the sand dunes and the sand is also kind of scars, or moderate availability ok. So, this sand dunes can be so these are the different shapes of this dune this is barchan dunes which has some crescent or some C shaped, C shaped crest. Then we have a star dunes where the wind from different directions are equally responsible are ok.

Then transverse dunes which forms in the which acts on the one particular ridge ok. Then we have parabolic which is exactly which is kind of opposite to the barchan dunes which

inverted U, inverted C here or U shaped. Then the longitudinal dunes which floor is actually where the flow is along the ridge ok, so these are parallel to the sand dunes.

The flow is parallel to the sand dunes here ok. So, here we are categorized the dunes based on the wind and sand availability ok. So, in barchan dunes we mostly get steady wind in mostly in one direction. In star we get study steady flow, but mostly steady direction, but changed steady wind, but changing it is direction ok. Then transverse dunes steady and moderate in one direction, parabolic steady wind with strong magnitude in one direction, longitudinal the steady and strong wind in one direction ok. So, let us see these different types of dunes in the next slides ok.

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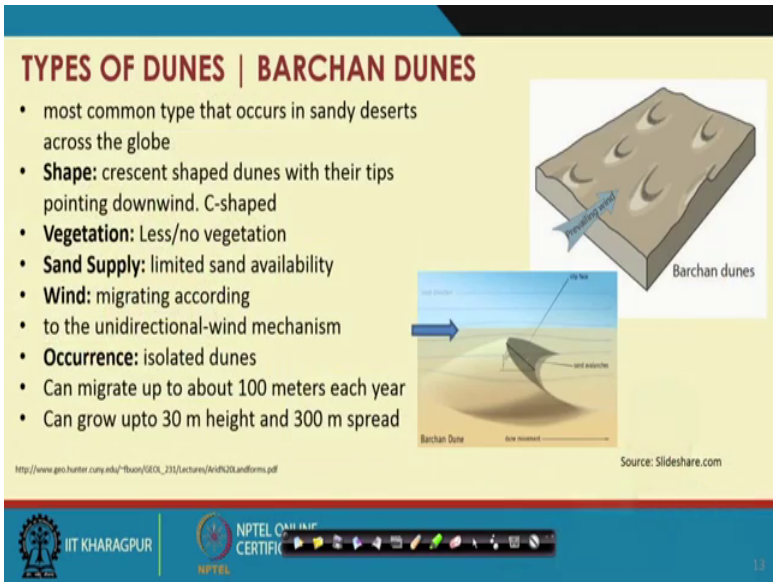

So, this is actually first let say that barchan dunes are they are also known as the crescent dune. So, this types of dunes actually mostly observed in the sandy desert across the globe ok. So, the shape of this dunes are actually kind of C shaped crescent shaped dunes with their tips pointing downwards. So, this is the tips are pointing down wards ok.

And here there is a less availability of or no vegetation availability. The sand supply is limited here the sand supply is limited and the flow is mostly steady here. The winds migrating winds are migrating according to unidirectional wind mechanism.

So, wind flow is mostly is unidirectional, but they migrate ok. So, this dunes are migrating according to the unidirectional wind mechanism, occurrences these are

actually mostly isolated dunes located are different place over that region. And it they can migrate up to 100s of meters each year ok. And they can grow up to 30 meter in height and they can be spread around 30 meter in distance ok so, this is a barchan dunes ok.

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So this is example of barchan dune, this is a image of barchan dune. So, here we can see movement of barchan dune by erosion of windward face and deposition on slip face. So, slip face there is a deposition and on windward side the erosion is taking place ok.

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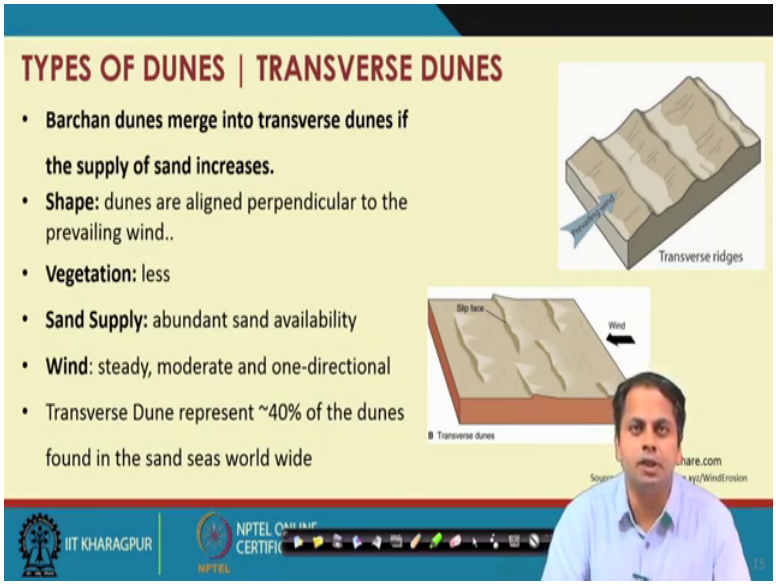

Now, next type is a transverse dune. So, these are these are actually the very much similar to barchan dunes, but the when the sand supply in the barchan dunes when it increases then they convert into the merge in to transverse dunes. So, barchan dunes merge into transverse dunes if the supply of the sand increases ok. So, these are the transverse dunes, so these are the transverse ridges and flow is in mostly in unidirectional flow so, we get series of dunes ok.

So, shape dunes are aligned perpendicular to the prevailing wind as you can see the dunes are actually perpendicular to the prevailing wind direction. Vegetations are vegetation is less and sand supply is mostly abundant, winds are actually steady and mostly one directional ok. This transverse dunes represent around 40 percent of the dunes found in the sand sea across the found in the sand sea worldwide ok.

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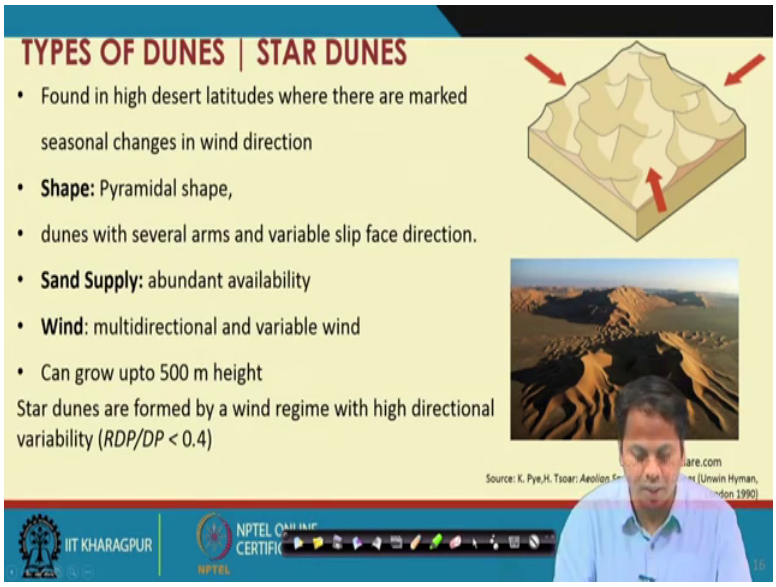

Now, next is the star dune ok so, this is found in high desert latitudes where their marked seasonal changes in wind direction. So, wind directional is changing vocationally here. So, we have different wind directions. So the moment of sand, or sand drift is in different direction. The shape is mostly pyramidal shape and this kind of dunes are mostly found in a desert latitudes ok.

These are dunes with several arms and variable slip face directions. So, slip face directions also different and the arms are there are many arms you can see here. Sand supply is abundant here, the wind is multidirectional and variable in nature and they can

grow up to 500 meters of height. Star dunes are formed by a wind regime with high directional variability that is a ratio of RDP by DP; if it less than 0.4 ok.

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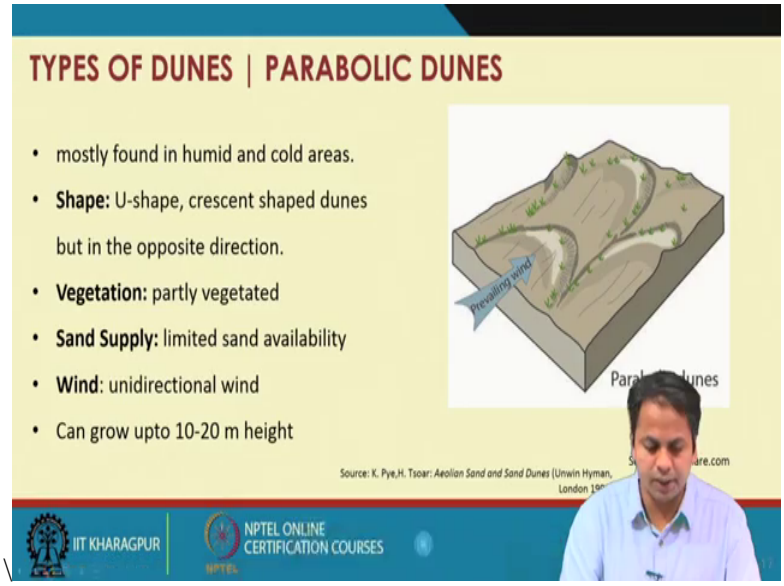

So, next type is a parabolic dune; so, this is a inverted U kind of dune so, these are mostly found in humid and cold areas. So, the shape of this dunes are U shaped or crescent shaped dunes, but in the opposite direction. In case of barchan it was C shaped, it is inverted C or you can call it as U; U shape. Vegetation is partly vegetated here, sand supply is limited and the wind is mostly unidirectional wind and they can grow up to 10 to 20 meters of height.

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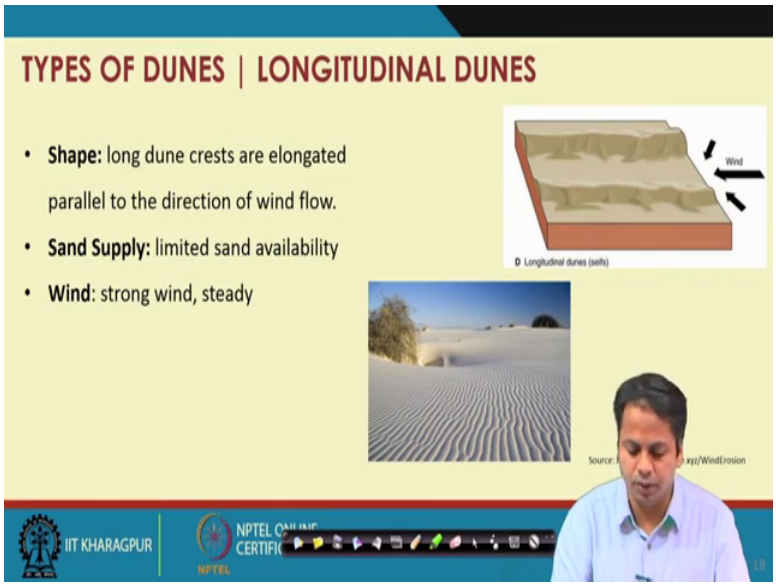

The next is the longitudinal dunes; so, you can see in the longitudinal as it name suggest. So, the wind is actually passing is parallel to the. So, this crests are actually parallel to the wind directions. So, winds is flowing along the around a parallel to the this ridges.

So, shape of this longitudinal dunes are shape long dunes are crests or elongated parallel to the direction of wind flow. So, when I said this winds are parallel to the as I said the winds are parallel to the crest ok, so these are parallel to the dunes. Sand supply; sand supply is a limited here and winds are mostly strong and steady.

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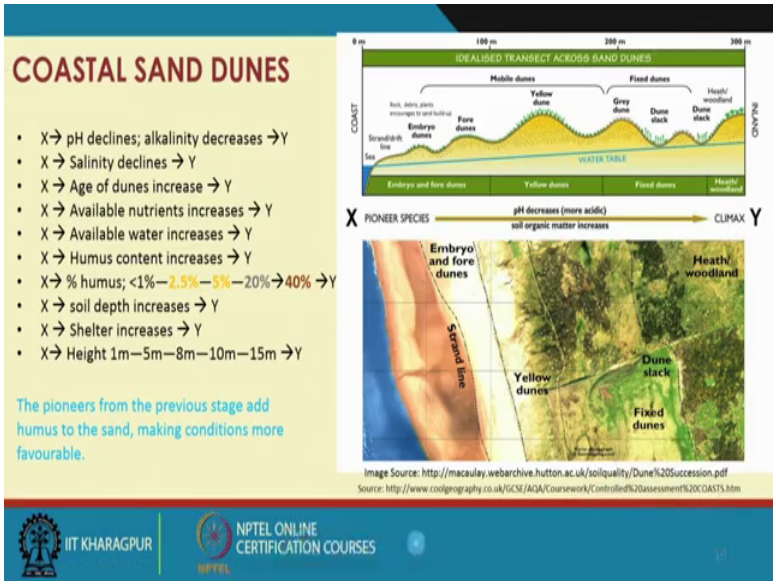

Now, let us see some of the important mechanism by with sand dunes form. So, this is the like we have obvious talking about the costal sand dunes. Let us talk about the costal sand dunes so, let us say this is a coast here let us first we see that the this image ok. So, this is the coast and this is approximate strand line and from there you can see the development of vegetation, and the dunes here ok.

So, the first face is the embryo or the fore dunes here the fore embryo and fore dunes form where the alkalinity or salt contents are very high at with very less vegetation. So, any small abstraction if it is present in the form of raw called debris they start accumulating they start accumulating sand over them. And in the subsequent time if the wind speed along with the wind they can be they can forms small embryo dunes ok.

So, and after that so here there is actually very less or no vegetation, but when you move when this sand dunes move here in directions. So these are actually moves these two dunes are mostly the mobile dunes ok. So, embryo dunes, fore dunes and yellow dunes they are comprise of mobile dunes. So, they changed their place ok, means like sand dunes they can migrate here. So, these are the yellow dunes these are relatively very young dunes ok.

So, we can see some kind of vegetation here in case of yellow dunes where as when you see us when you further move away on the sea shore you can see some kind of permanent vegetation cover here. So, and thus we can see some kind of soil formation also over this region ok, you can see some kind of permanent vegetation and soil formation permanent vegetation and soil formation. So, these are mostly known as the grade dunes.

So, grade dune and grade dune this is also this also sometimes comprises of dunes likes which has high moisture content and these are mostly the fixed dunes. And after that if you can see there is mature vegetation which has sufficient availability of vegetation as well as soil ok. So, what happens? So the over this regions initial stages these are actually the pioneer species ok. So, this here actually the species are mostly the pioneers ok.

So, when this pioneers the species when they die they form humus that humus which will be which can be use by subsequent species. So, here the species are mostly pioneer and as we move from X to Y the maturity increases and we will get more mature vegetation

as well as the soil here ok. So, to summarized this we can see if you moves from this pioneer from this place X to Y.

So, let us say we are the X is the pioneer species the species are mostly pioneer. And here the steady or equilibrium is established here in the climate stage. So, you can see pH is actually declines and alkalinity decreases as you move from one place to from along this direction. So, pH increases decreases and it becomes more acidic here it was more alkaline and here it is more acidic or you can find balance.

So, it becomes stable here the salinity also decreases when we move from this to the from X to Y. Similarly, the age of dunes increases so, these dunes are mostly mobile dunes the change there shape and the direction depending on the wind speed and this thing.

So, the shape gets change, but here the dunes are mostly stable. Then the available nutrition contents increases because the pioneer species they make favorable conditions. The pioneers species from previous stage and humus to the sand that makes condition more favorable for the subsequent stages of species. Then the available water content increases here, then humus content also increases see, the humus if you can see here it was around 1 percent, here let us say it was around 2. 5 percent, here it was in the great dune area it was around 20 percent.

And from the mature side are the heat or wood length region it is around 40 percent humus content. Soil depth also if you can see the soil depth also increases as you move from X to Y. The shelters also increasing and the height of the dunes are also you can see they are increasing as you move from X to Y ok. So here you can see around we can found around 15 to 20 meter height ok so, these are mostly the migration of how the sand dunes forms.

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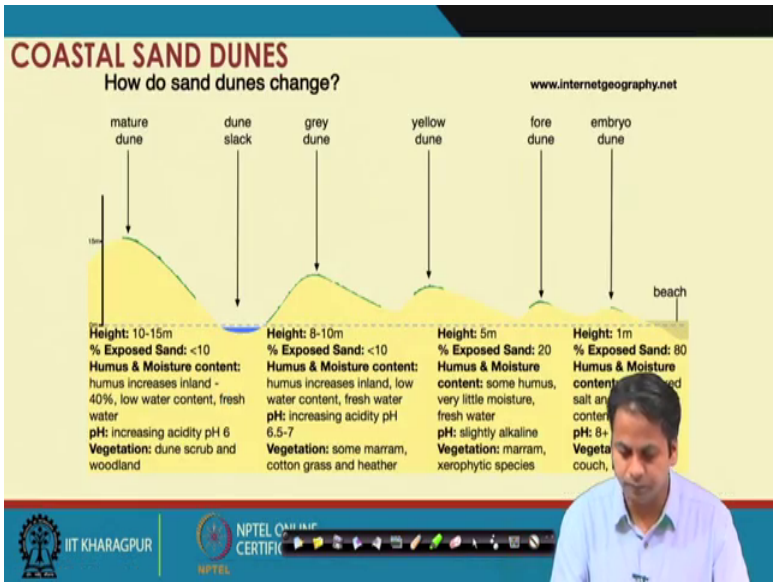

This is another image we represent the formation of dunes ok. This is a let us a beach you can see the height is increasing as you move in more inland, you must contents also increasing. Percentage sand and moisture is also increasing here and vegetation is becoming more permanent, here it was mostly sand and couch or lyme grass which can be sub merge in to the salt water. But here vegetation is more stable here and here also the vegetation here you can see some kind of marram or cotton grass are as there.

And pH is obviously, is actually less here compare to here say here the pH was the soil was mostly alkaline here it is more acidic or less alkaline. So, with that I will stop here for this lecture so, in this lecture we have seen various kinds of sand dunes, their formation and the process that was involved in the formation of sand dune.

And we have also see in the drift potential in different directions. And we have seen the; we have seen the formation of sand dune, coastal sand dunes how they form? And how the alkalinity and how the previous species they helps in they favors the formation of new species so that the equilibrium can be reached ok. So, with that we will stop here for this class.