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ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 48

Module – 6

Lecture – 2: Buried Structures

Welcome to lecture series in the course advanced geotechnical engineering we are module 6 lectures 2 on buried structures.

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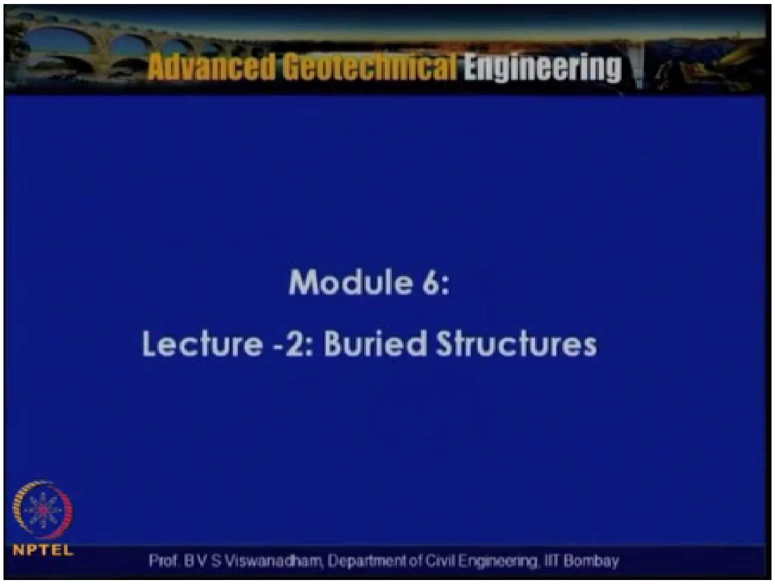

So in the previous lecture we introduced ourselves to Marston's load theory.

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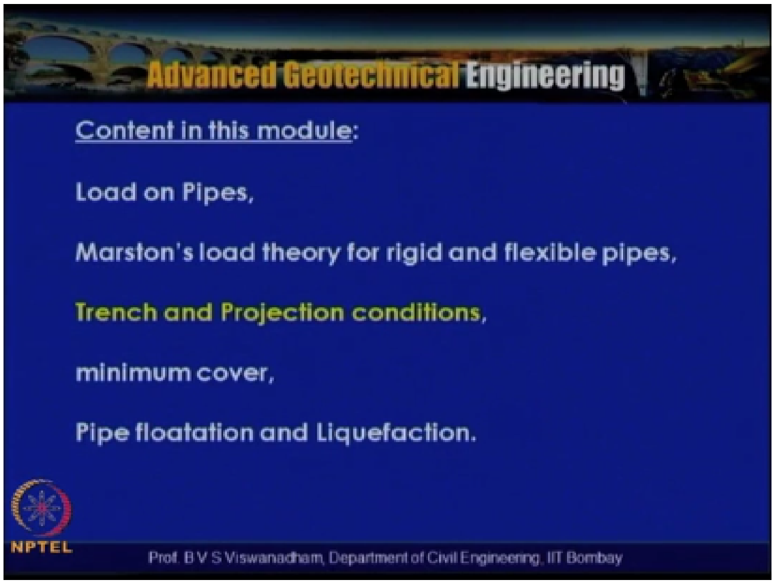

And then we have understood about the definitions about the different trench and projection conditions now in this lecture we will try to look into the chef differences between flexible and rigid pipes and Marston's load theory for different trench and projection conditions.

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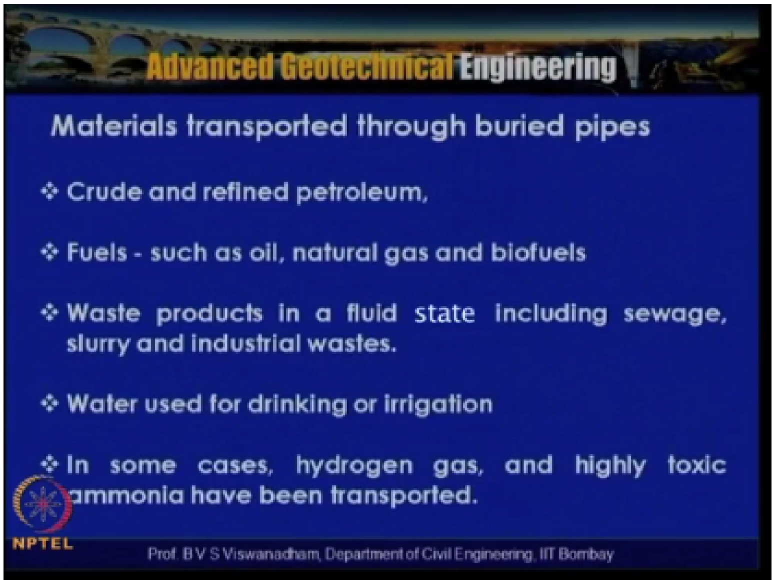

Before looking into that let us look into what are the significant of significances of buried pipes or buried conduits and what materials are usually transported through these buried pipes the materials transported through buried pipes are basically crude and refined petroleum, and flues such as oil, natural gas and bio fuels and some power plants can also have the cooling water pipe lines.

And the waste products in a fluid state including sewage, slurry and industrial wastes, and some pipes are also buried pipes are also used for water transporting water for drinking and irrigation and in some cases, hydrogen gas and highly toxic ammonia have been reported to be transported.

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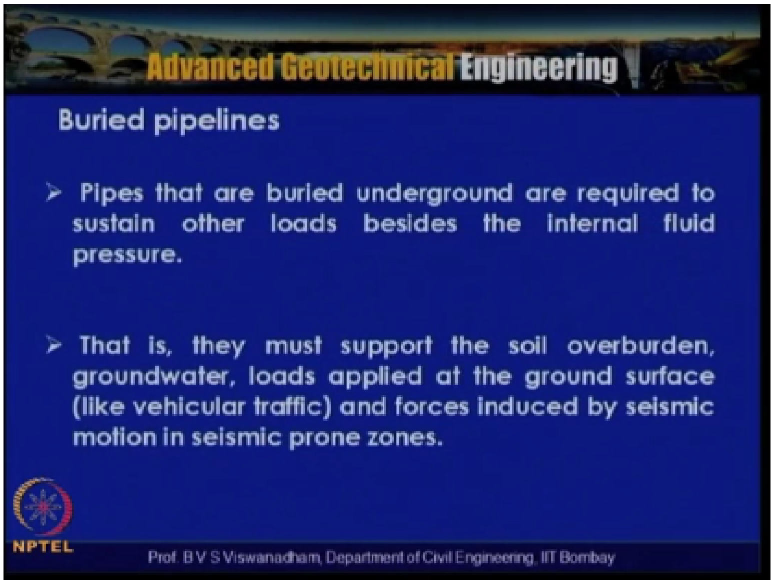

So pipe lines that are buried under ground are required sustain other loads besides their internal fluid pressures so pipe lines that are buried under ground are required sustain the other loads like 1st sulphate and then due to vehicular loads or and due to are due to some seismic lopes, that is they must support this soil over burden ground water and loads applied at the ground surface like vehicular traffic and forces induced by seismic motion in seismically prone areas.

That means is that this buried pipe lines must support the soil over burden ground water and load applied at the ground surface due to load due to vehicular traffic and forces induced by the seismic motion in seismic prone zones.

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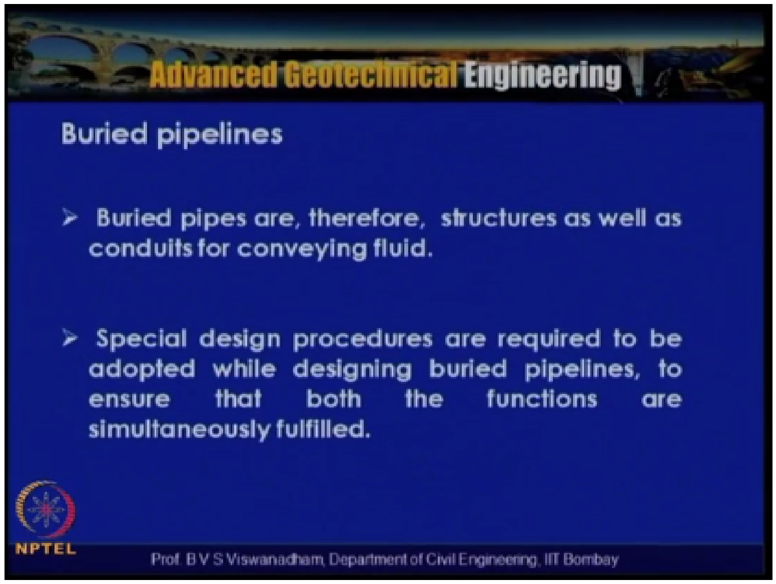

So buried pipelines are therefore the structures as well as conduits for conveying fluids and this special design procedures required to adopted while designing buried pipe lines to ensure that both the functions are simultaneously fulfilled that means that the it will servile a structure as well as conduit so the special design producers are required to be adopted while designing this buried pipe lines and to ensure both the functions are simultaneously satisfied. As the pipe lines are buried more landscape can be utilized for construction above the ground.

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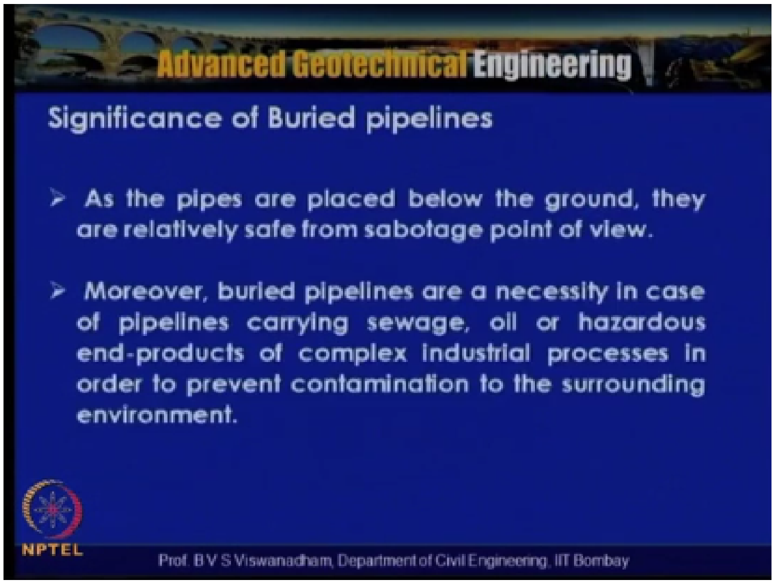

So that is one of the tributes of using buried pipe lines and buried pipes lines ensures minimum number of bends and crossing along the length of the pipe as they can pass in a relatively straight manner below the ground so the buried pipe lines you know ensures minimum number of bends and crossings along the length of the pipe as they can pass in a relatively straight manner below the ground. Thus in turn ensures the minimum loss because if ensure with less number of bends it ensures minimum losses due to bending and joint.

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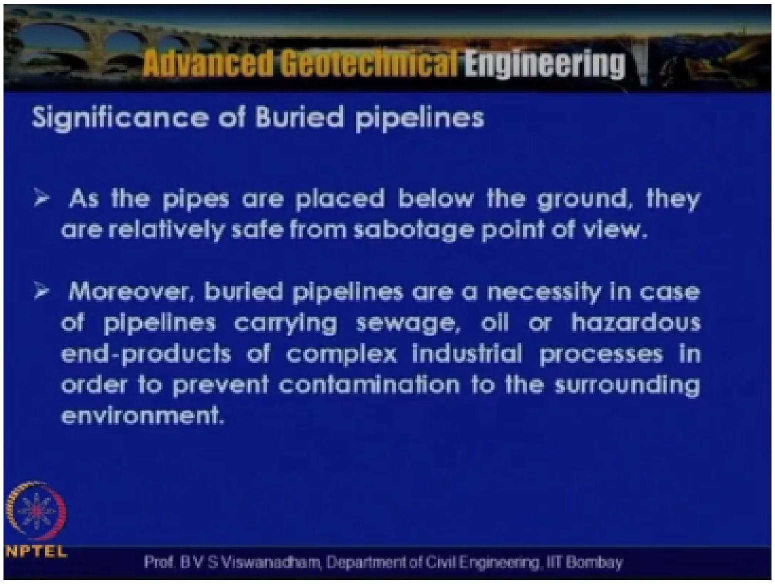

And as the pipes are placed below the ground they are relatively safe from the sabotage point of view, so that is another you know important issue now a days as because these pipes are placed below the ground they are required to be ensured the safety as to be ensured for any sabotage point of view more over this buried pipe lines are necessary in case of pipe lines carrying sewage oil or hazardous end products of complex industrial process in order to prevent contamination to the surrounding environment.

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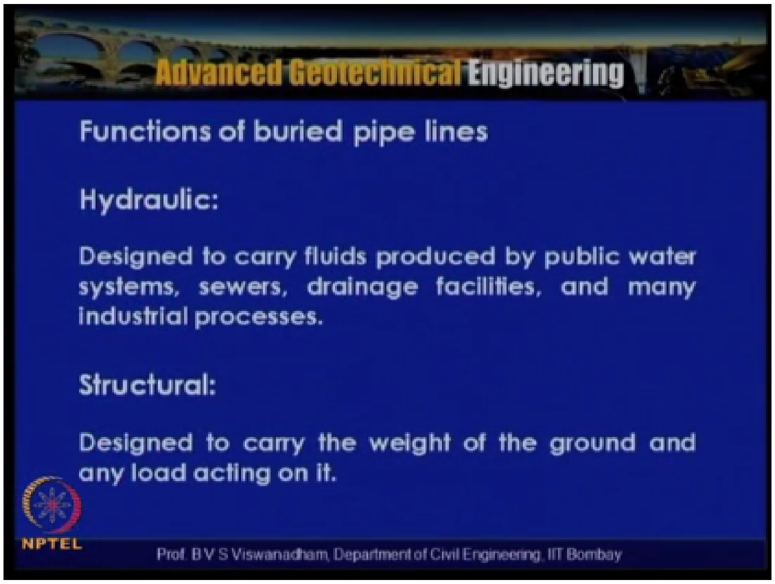

So the function of the buried pipes line are hydraulic and structural if you look into it the hydraulic requirement is that designed to carry fluids carried by public water systems sewers drainage facilities and many industrial process and the structural they are basically designed to carry the weight of the ground and any load acting on it, so from the structural point of view the pipe need to designed or buried pipe need to be designed to carry the weight of the ground and any load acting on it.

So before looking into the Matson's theory let us look into you know the different type like again ditch conduits and projecting conduits.

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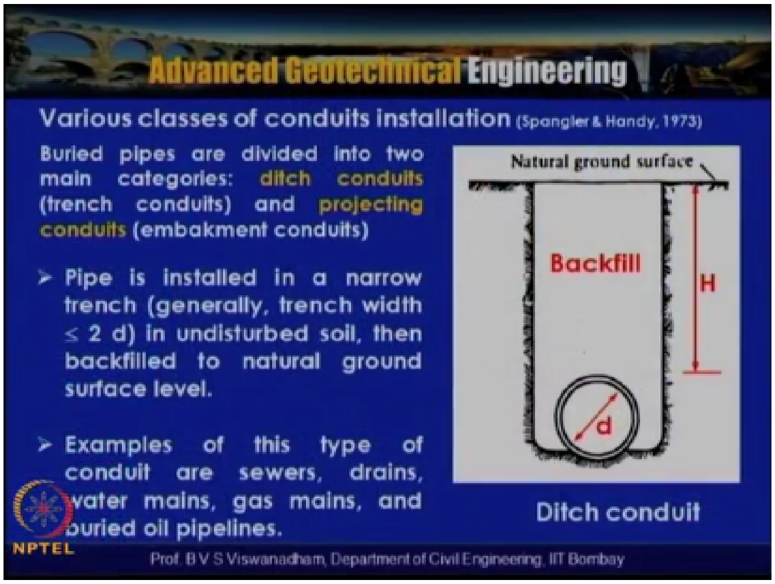

So we have introduced ourselves like buried pipes are divided into two main categories one is called ditch conduits and a projecting conduits in the pipe is installed in a if the pipe is installed in a narrow trench generally less than the two time the diameter of the pipe in undisturbed stable soil the n the back fill to the natural ground surface level. Then this is called you know the ditch conduit the examples of this type pf conduits are sewages drains water mains and gas mains and buried oil pipe lines.

So if the pipe is installed in a narrow trench generally the trench width less than two times the diameter of the pipe in the undisturbed soil then back fill to the natural ground surface and this type of conduit category is called ditch conduit.

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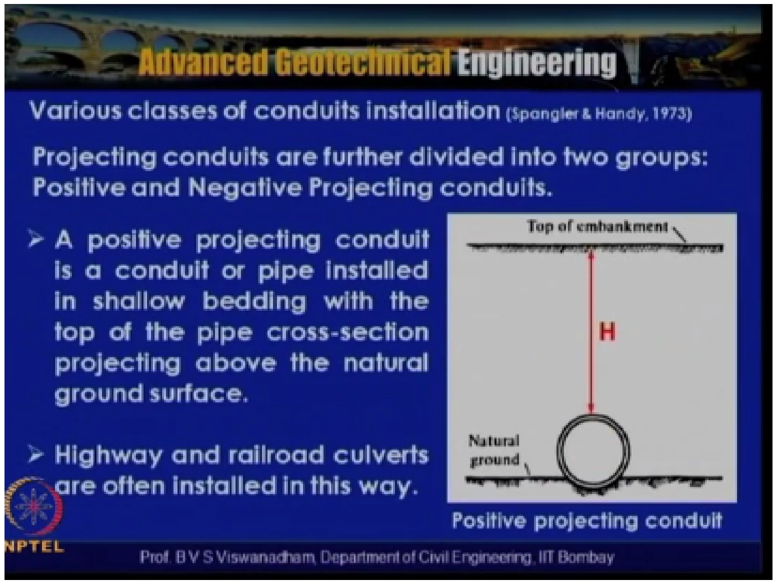

And the projecting conduits are basically two types one is called positive projecting conduit and negative projecting conduit in the positive projecting conduit basically it is a conduit or a pipe installed in a shallow bedding with the top of the pipe cross section above the natural ground surface so if the top of the pipe cross section is above the natural ground surface then it is called as a positive projecting conduit.

Generally for high way and railway and rail road culverts the positive projecting conduits are installed a positive projecting conduit is a conduit or a pipe installed in shallow bedding with the top of the pipe cross section projecting above the natural ground surface, so highway and railways rail road culverts are basically installed in this way.

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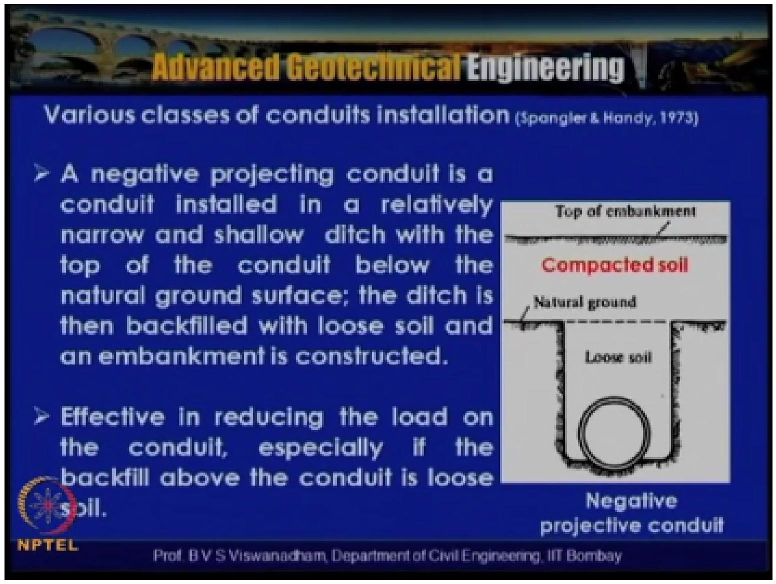

And negative projecting conduit basically is a conduit installed in a relatively narrow and a shallow ditch with top of the conduit below the natural ground surface that means that here this is the natural ground surface the top of the conduits surface is below the natural ground surface so the is the reason why it is called as negative projecting conduit and the ditch is then back filled with loss soil and amendment is constructed.

So basically that this is done then back filled with a loss soil and then amendment is reconstructed and here the amendment is with the compacted soil so this is effective reducing the load on the conduit especially if the back fill above the conduit is loss soil so effective in reducing the load on the conduit especially if the back fill above the conduit is a loss soil.

So negative projecting conduit is a conduit in a which is installed in a relativity narrow and a shallow ditch with the top of the conduit is top of the conduit below the natural ground surface the ditch is then back filed with a loss soil and the amendment is constructed so this is basically effective in reducing the load on the conduit especially if the back fill above the conduit is a loss soil.

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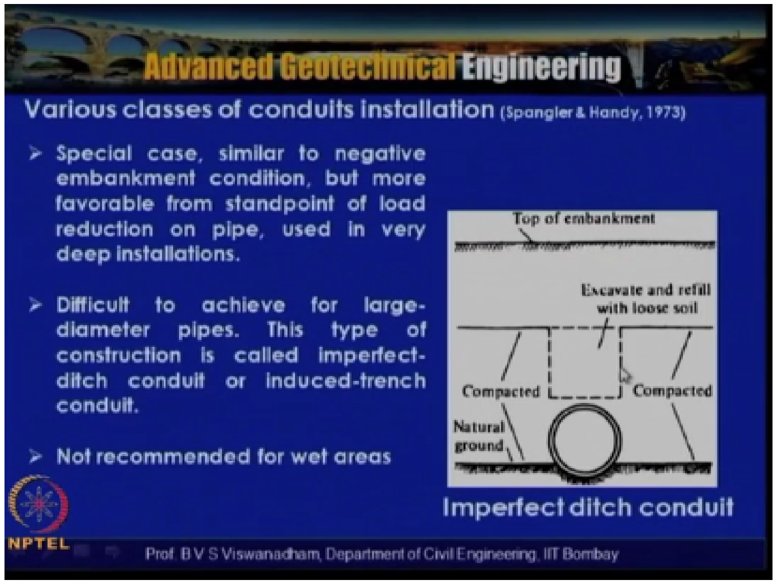

Then another case where in which is called as imperfect ditch conduit condition where it is similar to relative amendment condition but more favorable from stand point of load reduction in pipe used in very deep installations so basically this is difficult to achieve for large diameter pipes and this type of construction is called imperfect ditch conduit or induced trench conduit condition.

Where the top of the pipe is above the natural ground level and which is actually filled with a compacted fill and above the pipe it is actually placed with loss soil so this actually you know process will invite a seepage into the area and which actually entrenches the stability of the pipe so because of that this is not recommended for the wet areas and this type of category of installation of the pipe is called imperfect ditch conduit or induced trench conduit condition.

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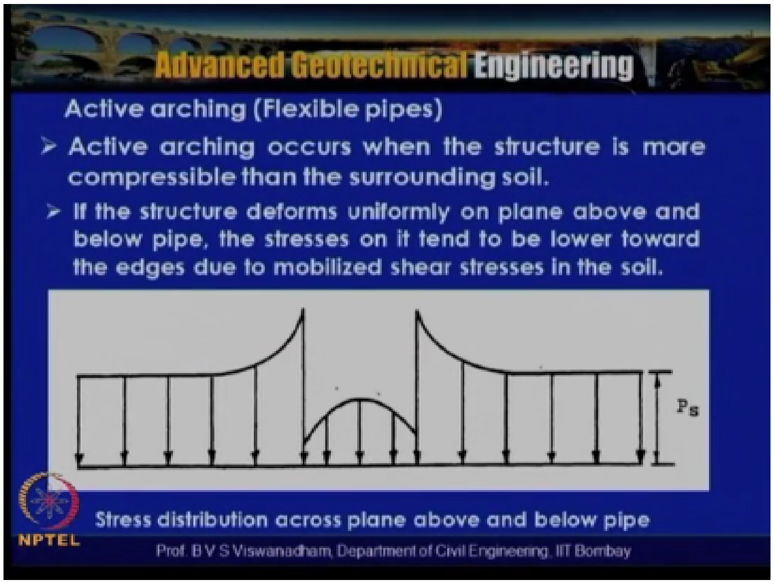

So then we also have discussed about the active arching and a passive arching then we said that this active arching occurs predominantly in flexible pipes and active arching occurs when the structure is more compressible like let us say a flexible pipe then the surrounding soil so if the structure deforms uniformly on the plane above and below the pipe then the stress on it tend to be lower toward to edges an due to the mobilize shear stress in the soil.

Because here in the in case of active arching what will happen is that the pipe settles more than the surrounding soil so in the process what will happen the load which is transparent to the pipe is actually less so if the structure deforms uniformly on the plane above and below the pipe the stress on it tent to be lower towards the edges and due to the mobilize shear stress in the soil so the stress distribution is actually shown here this is at the location of the pipe this is the diameter of the pipe.

This width is the diameter of the pipe and this is the one of the edges of the pipe and this is one of the edges of the pipe so the stress distribution cross the plane above and below the pipe.

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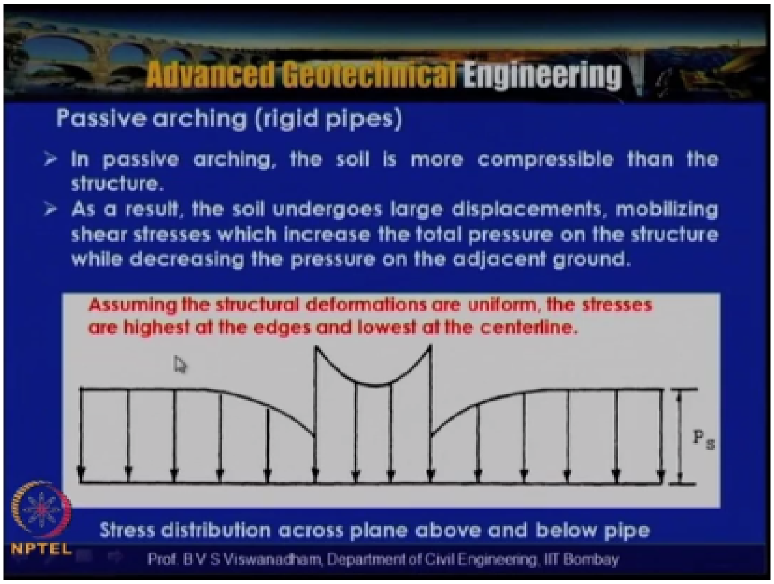

And passive arching basically this is predominant in rigid pipes the soil is more compressible than the structure that means that the pipe will not undergo any settlements the surrounding soil undergoes settlements as a result the soil undergoes large settlement the mobilizing shear stress which increase the total pressure on the structure while decreasing the pressure on the edges underground.

So here assuming that ten structural deformations are uniform the stress are highest at the edges and lowest at the center so the stress distribution across the plane above and below the pipe is obtained like this assuming that structural deformation are uniform the stress are highest at the edges and lowest at the centre line this is because participation of passive arching particularly for rigid pipes whet the soil actually more compressible that the structure.

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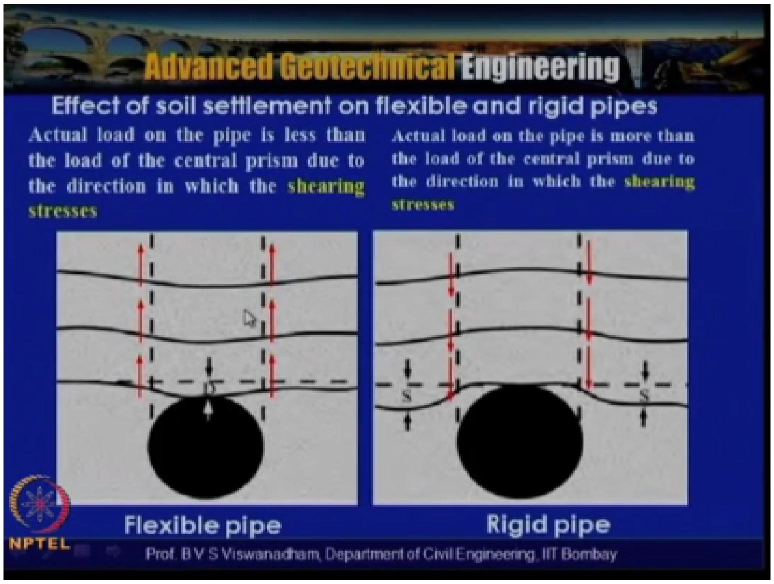

So here the effect of soil settlement on flexible and rigid pipe is shown here in case of flexible pipe it can be seen here the pipe undergoes more settlement than the surrounding soil in case of rigid pipe the surrounding soil undergoes more settlement than the pipe so in this case the this the external prism on the left hand side and this is the external prism on the left right hand side and this is internal prism can be seen that this shear stress are acting down and imposing the load on the pipe in this case what is happening is that because the pipe is steeling more than the surrounding soil.

There is a resistance which will offered from the this external prisms on the left hand side and right in case of a flexible pipe so the actual load on the pipe is less than the load on the central prism due to the you know the direction in which the shear stress are acting similarly here actual load on the pipe is more than the load on the central prism due to the direction in which the shearing stress are acting so here the actual load on the pipe is more than the load of the central prism so the actual load on the pipe will be more than the load of the this central prism that is that sulphate of this prism.

In which this is because is attributed to the direction in which the shear stress are acting so in this case you can see that the surrounding soil is settle in more than the surrounding soil is settling more than the structure under consideration that is nothing but a rigid pipe.

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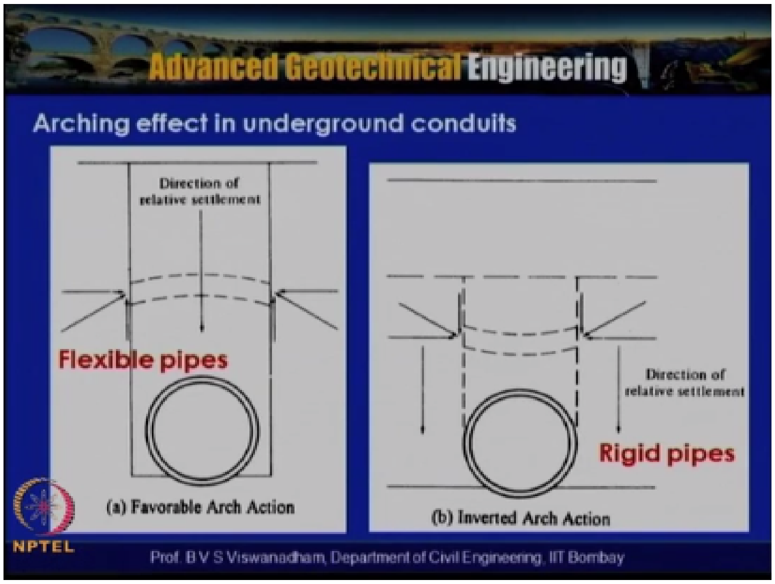

So this is once again which is actually shown in a pictorial way the arching effect in underground conduits particularly for flexible pipes the this actually acts like a this is the direction of relative movement and here in this case this is the direction of relative movement so here the for rigid pipes inverted arching action take place in case of flexible pipes the favorable arching action takes place like this.

So that direction movement is this like this and this side and this side there is a resistance so we can see this arch which is actually formed which is favorable like this for this for the flexible pipes in this case you know the shape of the arch is like this and the direction of relative movement is downward here and this is inverted arch action for the rigid pipes.

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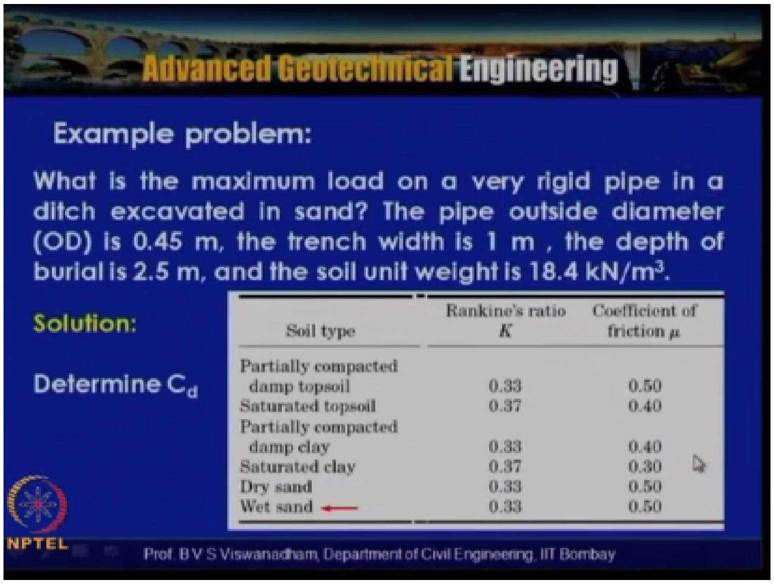

Now let us based on the pervious discussion which we have done in the previous lecture let us look into this example problem so we need to calculate what is the maximum load on a very rigid pipe in a ditch excavated in sand and the pipe outside the diameter pipe of the pipe outside diameter that is nothing but the outer diameter of the pipe is 0.45m and the trench width is about 1m and the depth of the burial is 2.5m and the soil unit weight is 18. 4kN/m^3.

So the soil unit weight is about 84 18.4 kN/m^3 so first of all in this solution what we need to do is that we need to find out what is Cd so here in this case if we assume it as a wet sand the rand and ratio k is obtained as 0.33 and coefficient of friction which is nothing but 0.5 coefficient of friction μ is given as 0.5. So the k μ is nothing but k x μ is about 0.165 that is 0.33 x 0.5 so first we need to determine Cd.

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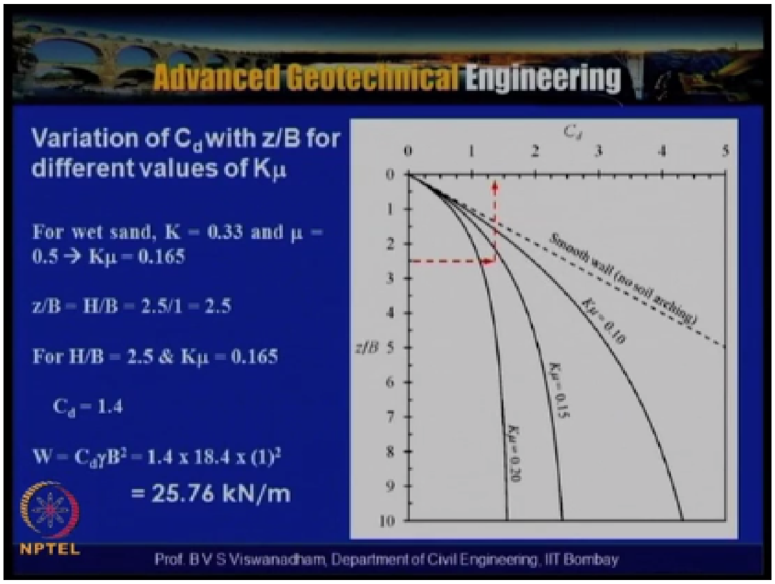

And this Cd can be obtained like this now by using this particularly curve variation of Cd with z/ B for different values of ku so we can see that as we have got for wet sand with k = 0.33 and μ = 0.5, k μ= 0.165 so it will be somewhere her so with that what we can actually get is that z/ B is nothing but H, H is nothing but the 2.5 m is the you know which is given as the depth of burial is 2.5m so 2.5 m / B tyat is 1 which is nothing but 2.5.

And for H/ B that is = 2.5 k μ = 2.165 for z/B = H/ B = 2.5 k μ = 0.165 we can read Cd here and the Cd works out to be 1.4 so with that what we can get is that w= Cd x γB^2 where in 1.4 x 18.4 x 1^2 so with that what we get is that it is nothing but a 25.76 kN/m so normally if you look the weight of this prism above this pipe which is nothing but if yiu say the unit weight is say 20kN/m^{3-} and the height is 2.5.

So it a nothing but γH x γH is nothing but that is 2.5 x γ that is 2.5 x 20 is about 50kN/m^2. So W = Cd γB^2 where 1.4 x 18.4 x 1^2 so with that what we can get is that to 25.76 kN/m.

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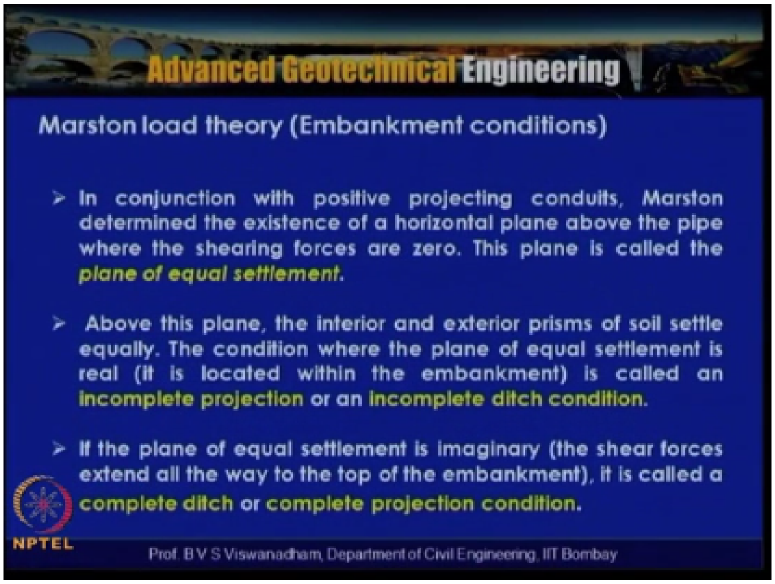

So in continuation of this discussion the Marston's load theory particularly for amendment conditions need to be highlighted we have done for the previous case for the you know for the trench conditions so in conjunction with the positive projecting conduits Matson's determined existence of horizontal plane above the pipe where the shear force are 0.

And if this plane this plane is called the plane of equal settlement that means that in conjunction with the positive projecting conduits which are actually the where the top of the pipe is above the natural ground level a Marston's defined there determine the existence of the horizontal plane where the shear forces are 0 so this plane is actually called as the plane of equal settlement.

So above this plane the interior and exterior prisms that means that interior prism is nothing but the prism which is right above the pipe line and exterior prisms are the prisms on the left and right sides of the pipe so above this plane the interior and exterior prisms are soil settle equally and the condition where the plane of equal settlement is real is called an incomplete or incomplete projection or incomplete ditch condition.

If the plane of equal settlement is imaginary if the plane of equal settlement is imaginary that means that the shear forces extended all the way up to the top of the amendment then it is called a complete ditch or complete projection condition if the plane of equal settlement is imaginary and the shear forces are will extend all the way up to the top of the amendment then it is called as complete ditch or complete projection condition.

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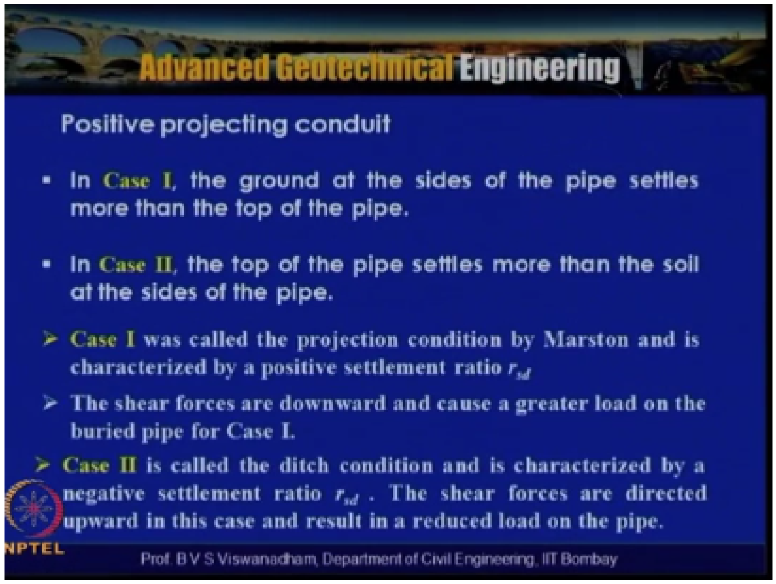

So there are 2 cases which are actually considered for the positive projecting conduits in case 1 the ground at the sides of the pipe settles more the top of the pipe so that is for a rigid pipe the ground at the sides of the pipe settles more than the top of the pipe in case 2 the top of the pipes settles more than the soil at the sides of the pipe this is for the flexible pipe.

So case 1 the ground at the sides of the pipes settles more than the top of the pipe in case 2 the top of the pipe settles more than the soil at the sides of the pipe, so in case 1 was called the projection condition by Matron and is characterized by positive settlement ratio that is γr_{sd} r_{sd} is nothing but positive settlement ratio this is for the where this is for called by te case 1 is called by the projection condition of Marston and is characterized by positive settlement ratio the shear forces are downward and cause a greater load on the buried pipe for class 1.
The shear forces are downward because the grounded the sites of the pipe settles more the top of the pipe because of that the shear forces are downward and causes a greater load on the buried pipe for case1 and case 2 is called the ditch condition and is characterized by the negative settlement ratio that is right the r_{sd} will be negative so the shear forces are directed upward in this case and resulted in the reduced load on the pipe this the shear forces are directed upward in this case is resulted in a reduced load on the pipe.

So there are so in the positive projecting conduit conditions derivation according to Marston's load theory the 2 cases where considered on case 1 is that the grounded at the sides settlements more than the top of the pipe and case 2 is the top settles more than the soil at the sides of the pipe with case 1 and case 2 and case 1 where the positive settlement ratio γ_{sd} r_{sd} is you know is used.

And where case 2 where the negative settlement ratio where the shear forces are down acting downward acting upward in this case and results in a reduced load on the pipe because case 2 the top of the pipe settles more than the soil at the sides of the pipe that is for a flexible case flexible pipe case now in this particular slide.

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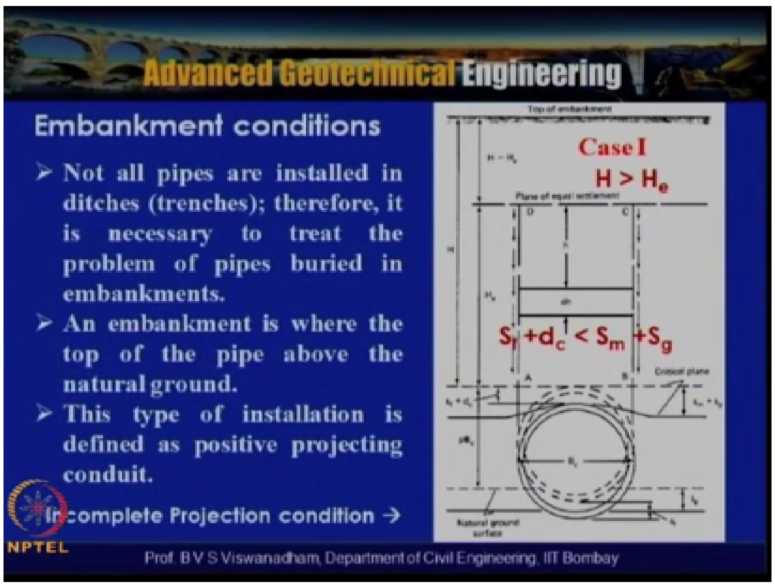

A case 1 is actually shown where H is the height from the top of the amendment to the top of the pipe and He is nothing but the height of the plane of equal settlement so this I the plane of equal settlement so this is the plane of equal settlement and this is the interior prism and this is the exterior prism one on the left hand side exterior prism on the right hand side where ion this particular case H is > H_e where H> H_e and S_f+ d_c so S_f+ d_c which is nothing but S_f is nothing but the side field.

And d_c is the deflection of the pipe is actually less than that S_m+ s_g that is the this Sm + Sg so here not all pipes are installed in you know in ditches and therefore it is necessary to treat the problem of pipes buried in the amendments and amendment is where the top of the pipe you know is project above the natural ground and this type of installation is defined and the positive projecting conduit and this condition where S_f+ d_c < Sm + Sg and H> He is called as incomplete projection condition.

So we had actually discussing about the amendment conditions as that not all pipes are installed in ditches therefore it is necessary to treat the problem of pipes buried in the amendment case also that is the reason why we are actually trying to reduced the expression by using the Marston's load theory. So that we can determined what is the load imposed on the pipe for the different conditions which are actually are going to be you know volume.

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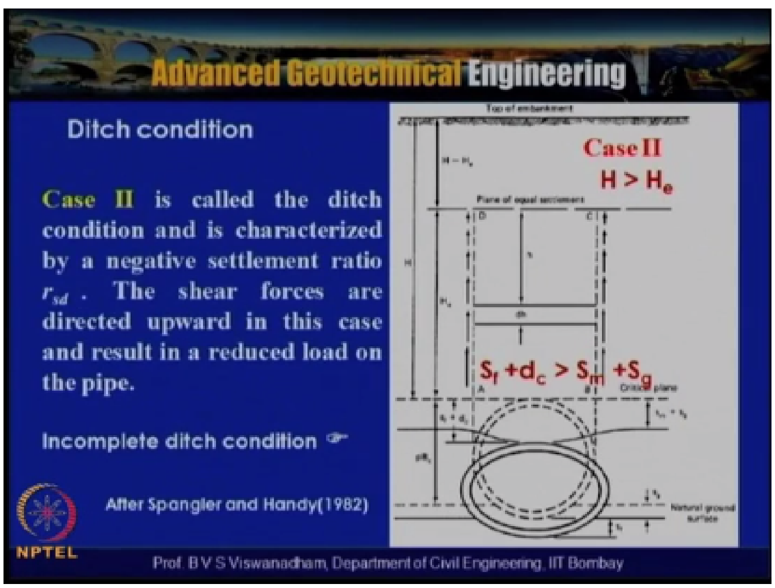

So in this case the case II where H is > He and $S_f + d_c$ that is the settlement of the fill and you know the d_c that is nothing deflection of the pipe is < than Sm + Sg so this case 2 called the ditch condition and is characterized by a negative settlement ratio that is r_{st} the shear forces are directed upward that can be seen here the shear forces are actually acting upward in this and result of this results in a reduced load on the pipe. So this particular condition of H> He and $S_f + d_c$ > Sm + Sg is called as incomplete ditch condition in case of the pervious slide.

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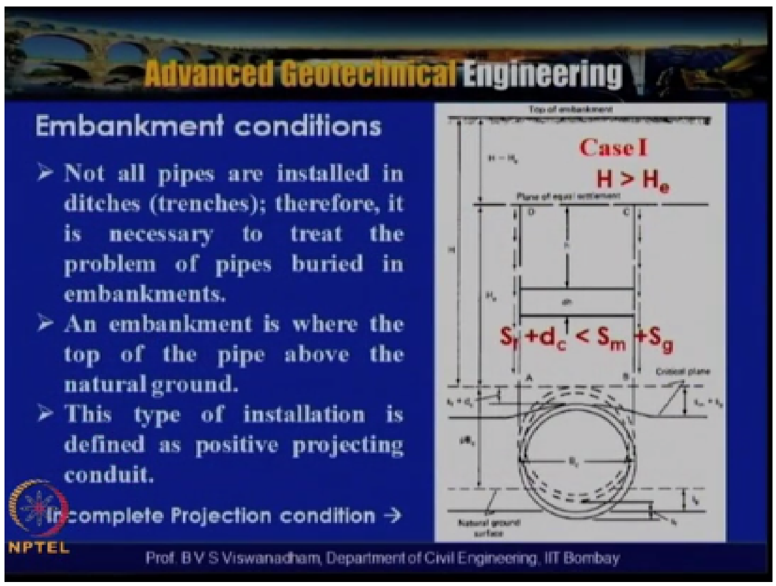

Where it can seen.

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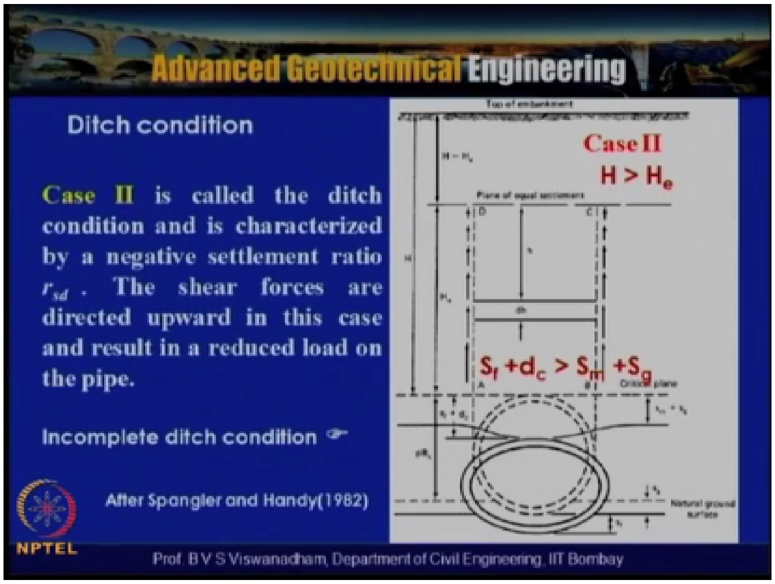

That the shear forces are actually acting downward the shear forces are acting downward so this actually contributes to more settlement on the you know below the critical plane here the critical pane is a plane at the top of the pipe so here can been seen that this is the critical plane so this particular portion is S_f+ d_c and this particular portion is Sm + Sg in this case also the critical plane you can see that the pipe actually settles more than the critical plane and the surrounding soils only settles this much Sm + Sg so this is S_f+ d_c where the settlement is actually very high because of the flexibility of the pipe because of the flexibility of the pipe.

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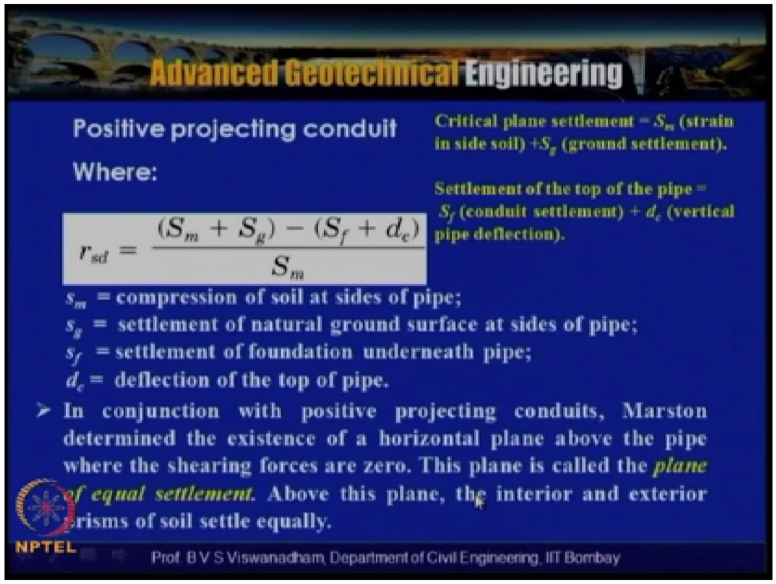

So here what is the S, Sm is nothing but the compression of soil at the sides of the pipe and Sg nothing but the settlement of the natural ground surface at sides of the pipe so Sm is compression of soil at sides of the pipe Sg is nothing but the settlement of the natural ground surface at sides of the pipe and Sf is nothing but the settlement of foundation underneath the pipe and d_c is nothing but the defection of the top of the pipe.

So Sf is nothing but the compression of soil at the sides of the pipe and Sg is nothing but the settlement of natural ground surface at sides of the pipe that means that you know the settlements are due to this particular this is the settlement of the foundation.

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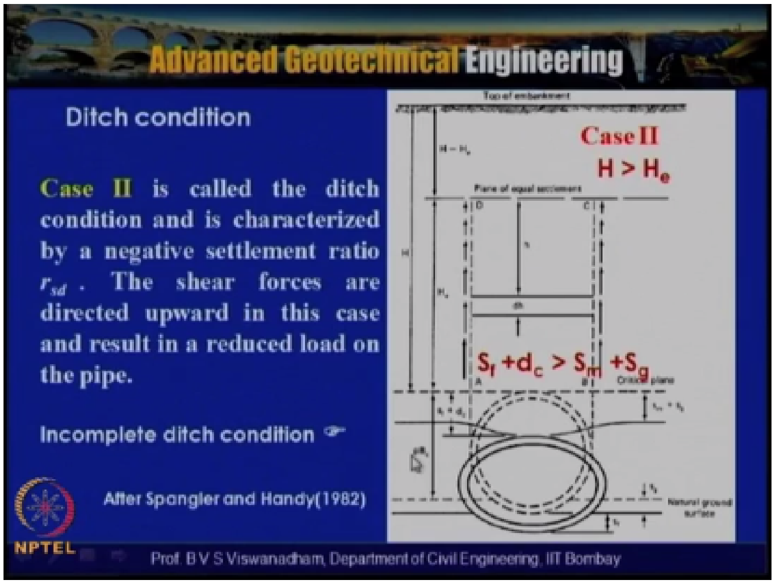

And this is settlement of the fill below the pipe this is sides of the pipe so this is actually what is being discussed and this is PBC the P is actually called as the projection ratio P is called as the projection ratio.

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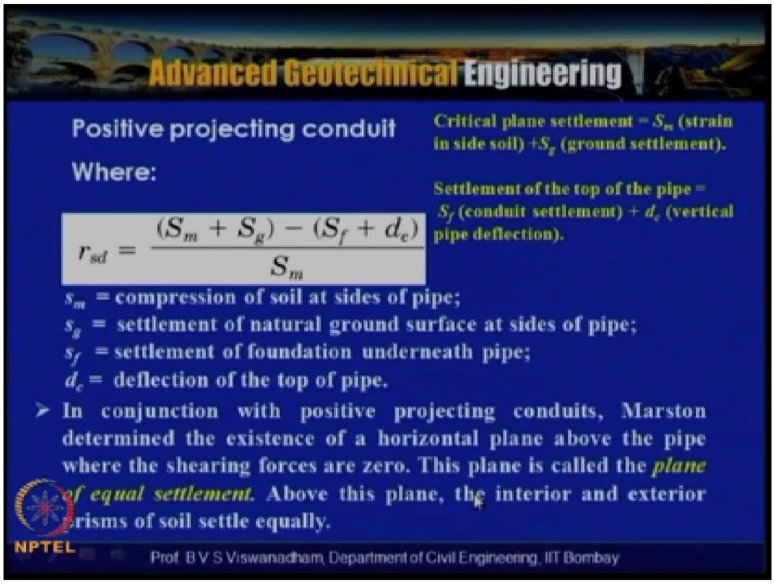

So Sf is the settlement of foundation underneath the pipe that is the settlement of foundation underneath the pipe.

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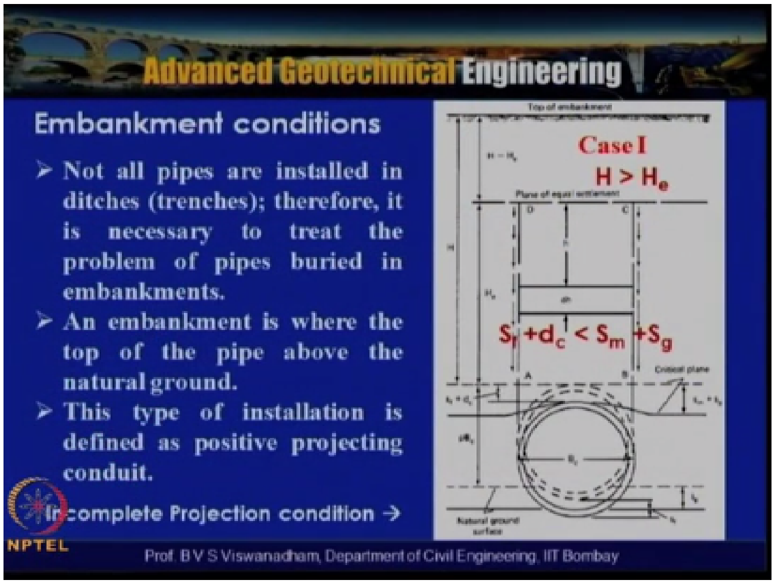

And that is here also it is shown Sf as the settlement of the foundation underneath the pipe.

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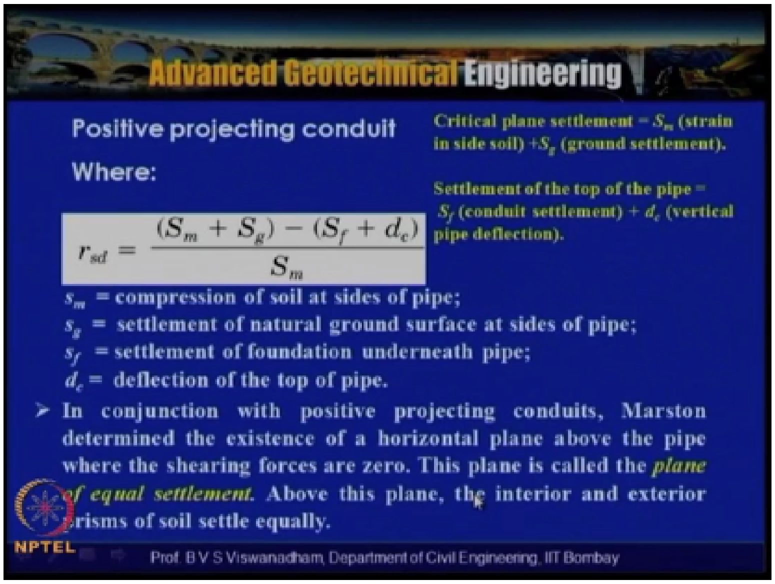

And Sg is the settlement of the natural ground surface at sides of the pipes that is settlement of the natural ground surface at sides of the pipes that is actually shown here.

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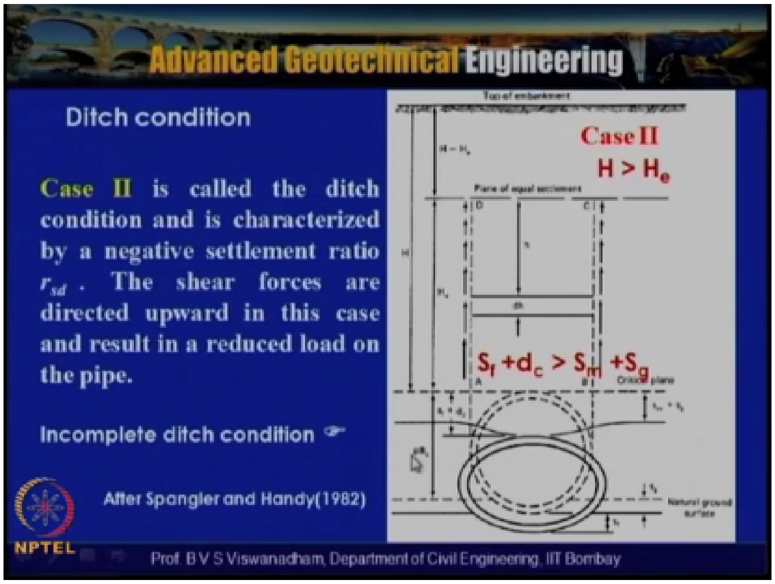

How much the natural ground surface is settling at the sides of the pipe.

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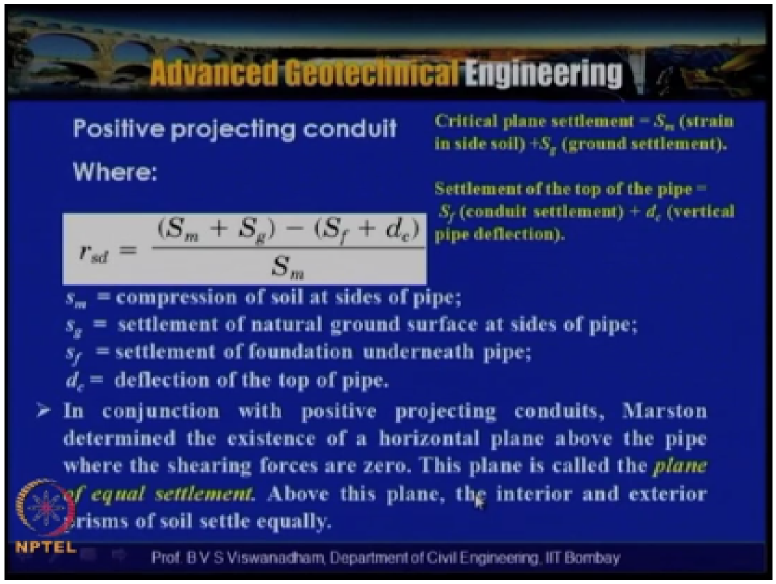

And Sm is the compression of soil at the sides of the pipe and settlement of the natural ground surface at sides of this Sf is nothing but settlement of the foundation underneath the pipe and d_c is the deflection of the form it of the top of the pipe that is dc is the defection at the top of the pipe okay so after having a you know defined the terminologies the settlement ratio is actually defined as Sm + Sg – S_f + d_c / Sm so for flexible pipes the settlement ratio is negative because S_f + d_c is more > than Sm + Sg so the ratio of Sm + Sg - S_f + d_c / Sm is defined as settlement ratio.

And critical plane of settlement is nothing but Sm that is the strain in side soil +Sg ground settlement and settlement of the top of the pipe = S_f + d_c which is nothing but the S_f conduit settlement and + d_c which is the vertical pipe deflection due to the property of pipe is the pipe defection this merely due to property of the pipe so in conjunction with the positive projecting conduits the Marston determine the existence of horizontal plane above the pipe.

Where the shearing forces are 0 so this plane is called the plane equal settlement so above this plane the interior and exterior prisms of the soil settle equally so in this in conjunction with the positive projecting conduits the Marston existence of the horizontal plane and above this pipe where the shear forces are 0 and this plane is actually called as the plane of equal settlement above this plane the interior and exterior presence of soil settles equally.

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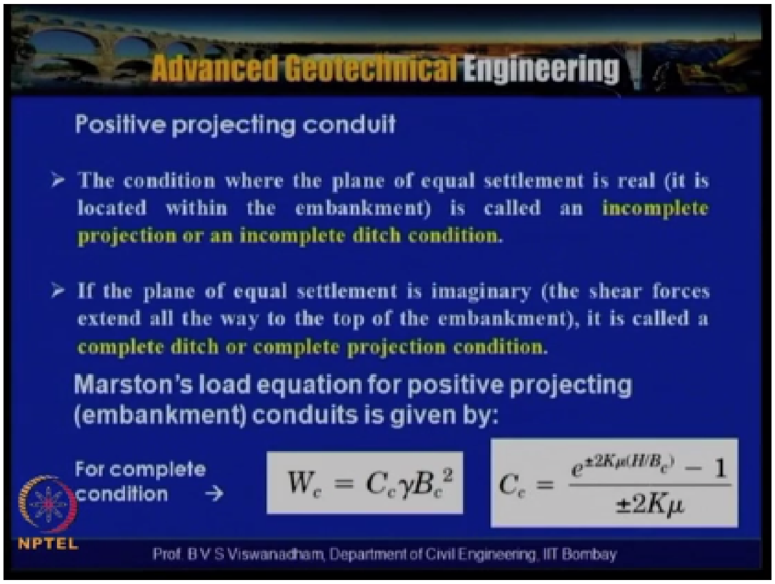

So for the positive projecting conduit in condition of our discussion the condition where the plane of equal settlements is real that is located with the amendment and is called as incomplete projection or incomplete ditch condition if the plane of equal settlement is imaginary that is the shear forces extend all the way up to the amendment.

This is called as a complete ditch are completely projection condition so for this the Marston load equation for positive projecting conduits is given and this is given by fore complete condition for complete concoction Wc = Cc x γ Bc^2 Cc is nothing but $e^{+-2K \mu \, x \, H/Bc}$ – 1/ + - 2k μ so please not that there are + - signs are there in expression for Cc so this is for complete condition where Wc = Cc x γBc^{2} where Cc = $e^{+-2K \mu \, x \, H/Bc}$ – 1/ + - 2kμ so the – signs are for the compete ditch condition and + sign for the complete projection condition.

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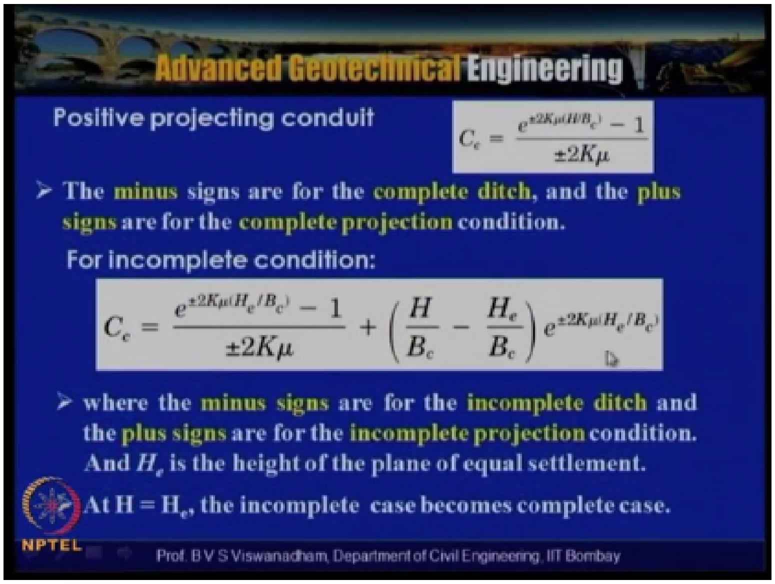

So in this particular expression the – sign is for the complete ditch condition and + are for the complete projection condition for incomplete condition you have to use this one where Cc = $e^{+-2K \mu \text{ x } H/Bc}$ – 1/ + - 2k μ + H/Bc- He / Bc x $e^{+-2K \mu \text{ x } H/Bc}$ so where – signs are for incomplete ditch condition and + is for the incomplete projection condition where – signs for the incomplete ditch and + signs for the incomplete projection conditions and He is the height of the plane of equal settlement.

So He is nothing but the Height of the plane of the equal settlement suppose if you assume that the height of the amendment and height of the equal settlement that is the plane of the equal settlement if they are equal so when a He = He and this is actually converted into this case is converted into Cc = e+- 2K μ x H/Bc – 1 / +- 2K μ x this thing so when we H = H μ this particular expression is actually converted into this one so this particular portion will get nullified.

So what we have is only this so at H= He the incomplete case becomes complete case the when He = He where that means that height of amendment = height of you know plane of = settlement then that case the incomplete condition gets converted into a complete condition so what we have done is that by using this different for the amendment conditions we actually have deduced a depending on the either flexible pipe or rigid pipe.

We actually have you know deduced the effect if I made efforts to calculate the load coming on to the pipe that is nothing but W= Wc = Cc x γ x Bc^2 now this Cc basically is a function of the ratio of the height of the cover to the pipe diameter so H is nothing but the height of the cover to the pipe diameter and the product of the settlement ratio γsd and projection ratio that is γsdp that γ sdp is nothing but the that is the settlement ratio product settlement ratio γsd and the projection ratio p.

And k is nothing but the rank in constant and μ nothing but the coefficient of friction so the value of the product k μ is generally taken as 0.19 for the projection condition and 0.13 for the ditch condition so this Cc is a function of H/ Bc and γsd x p k and μ, now we actually we have you know the 4 conditions have been classified according to Spangler.

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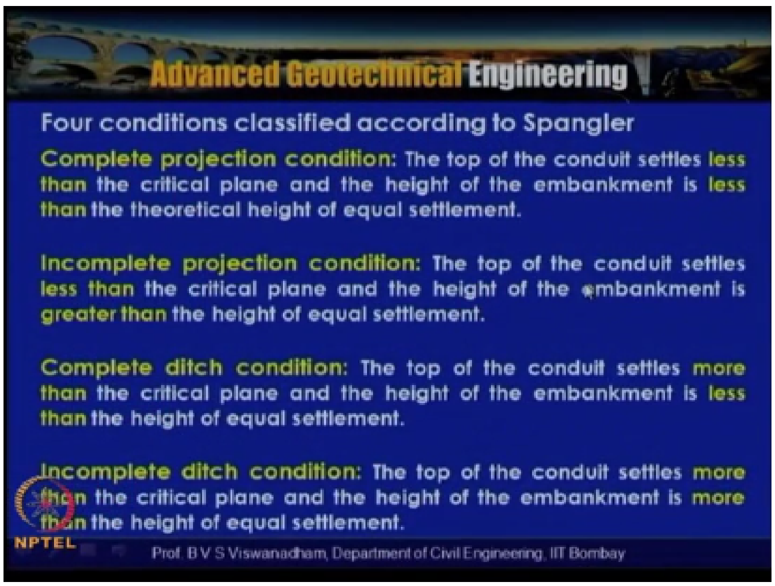

Based on the installation the complete projection condition is nothing but the top of the conduit settles less than the critical plane and the height of the amendment is less than the theatrical height of equal settlement that is called complete projection condition in complete projection condition the top of conduit settles lees than the critical plane that is the rigid pipe and the height of the amendment is greater than the height of equal settlement.

And in case of complete rigid condition the top of the conduit settles more than the critical plane and the height of amendment is less than the height of equal settlement which is imaginary case incomplete ditch condition with the top of the conduit settles more than the critical plane and height of the amendment is more than the height of equal settlements so we have complete projection condition and incomplete projection condition the difference between complete projection condition and incomplete projection is nothing but the top of the conduit settles less than the critical plane.

And the height of the amendment is less than the theoretical height of equal settlement so in the case of incomplete projection condition the top of the conduits settles less than the critical plane and the height of the amendment is > than the height of the actual settlements the case of the complete ditch condition the top of the conduit settles more than the critical pane and the height of the amendment is less than the height of the equal settlement the incomplete ditch condition the top of the conduits settles more than the critical plane and the height of the amendment is more than the height of the equal settlement.

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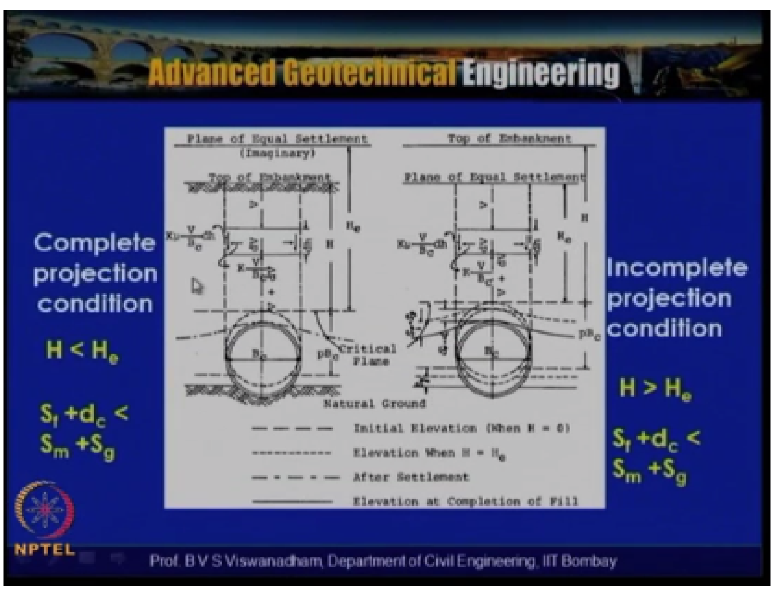

So these conditions are actually shown once again here where in the complete projection condition where height of the amendment that is this is the amendment and this is the natural ground level and this the unknown the top of the conduit is actually above the natural ground surface this is a positive projecting conduit and where the height of the plane of equal settlement which is above the height of the amendment.

That is H > He and $S_f + d_c$ is > Sm + Sd that means that here the surroundings soil actually settles more than the you know there is more than the this soil the foundation below right below the pipe and the deflection of the pipe, so Sf + dc > Sm + Sg so this condition is called complete projection condition where as so if you look into this the you know in order to reduce this you know for getting this $W = Cc \times \gamma Bc^2$ and for getting the different load conditions which we have discussed/.

The forces which are actually nothing but a the shear forces are acting like this in this case it is downward they are acting downward and these are the normal stress acting like this and so the what we have taken is that we have taken on the small element and integrated to the entire area so that we could actually get the entire load acting on the buried conduit so in this case you know the plane of the equal settlement is less than the height of the amendment.

You can see that H> He so H is actually > He so this is the critical plane so this is the critical plane also in this case where Sf + dc is < Sm + Sg Sf + dc is < Sm + Sg so this is incomplete projection condition where incomplete projection condition is here so here initial elevation when H = 0 when initial elevation when H = 0 that is shown here and elevation when H = He elevation when H = He and after settlement and elevation at completion of the fill which is actually shown here.

So incomplete projection condition where incomplete projection condition means the top of the conduit settles less than the critical plane and height of the amendment is > than the height if the equal settlement that is what actually as been shown here height of the amendment is actually more than He and the pipe actually said this > than the that is Sf + dc settles > than the Sm + Sg that is again here shear forces are acting downwards it will be both this incomplete complete projection condition incomplete projection condition which are directly shown both are for the rigid pipe only.

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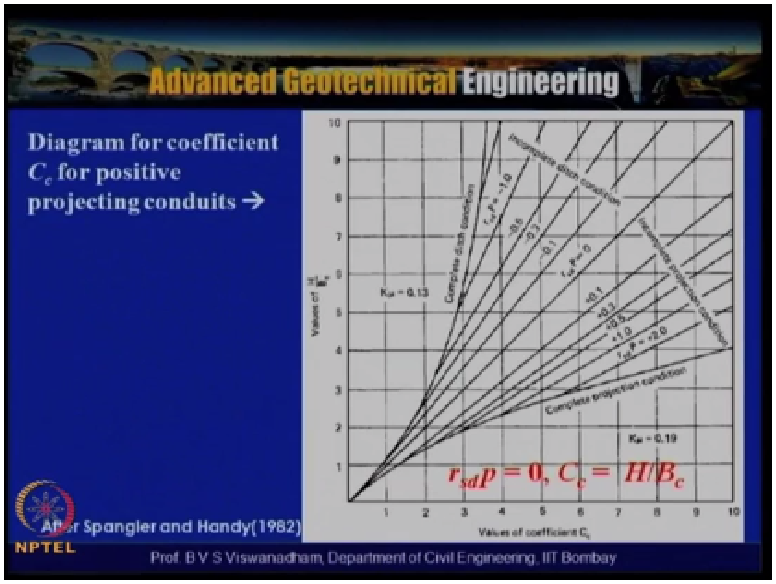

So in order to compute this Cc value by considering the factors which are actually there for different possible condition which can be possible diagram for the coefficient of coefficient Cc for positive projecting conduits is actually given here where this curve is for values for the coefficient of Cc and x axis here the range from 0 to 10 here and the values of H / Bc for different values of H/ Bc they are given here and this side it is actually for k μ = 0.19 and this side is for k μ = 0.13.

And at this along this central line that $r_{sdp} = 0$ the along the central line $r_{sdp} = 0$ when $r_{sdp} = 0$ that means that Cc coefficient will be equivalent to H/ Bc whatever H/Bc will be there and that is equivalent to Cc so this condition when $r_{sdp} = 0$ is nothing but you know H/ Bc so when yhiu say that Wc = γ x Wc = γ x Cc x H/ x Bc^2 then Cc = H/Bc so what we get is the load on the pipe is nothing but W c = γ x H x Bc.

So here the negative settlement ratios are given that is – 0.1, -2, -0.2, - 0.5 and -1 so here the – settlement the - r^{sdp} ratios are r^{sdp} term which is in – is given here and positive is given here and along this line this is the complete projection condition and this is the complete ditch condition and this is for the different incomplete projections conditions.

So in this slide the diagram for the coefficient for Cc for positive projecting which is given where in this is after a Spangler and handy 1982 where in for different values if you look into that r^{sdp} = 0 it gets converted into Cc = H/ Bc with that the Wc = γ x H x Bc that is actually about so this is for complete ditch condition incomplete ditch condition incomplete projection condition and complete projection conditions they can be obtained.

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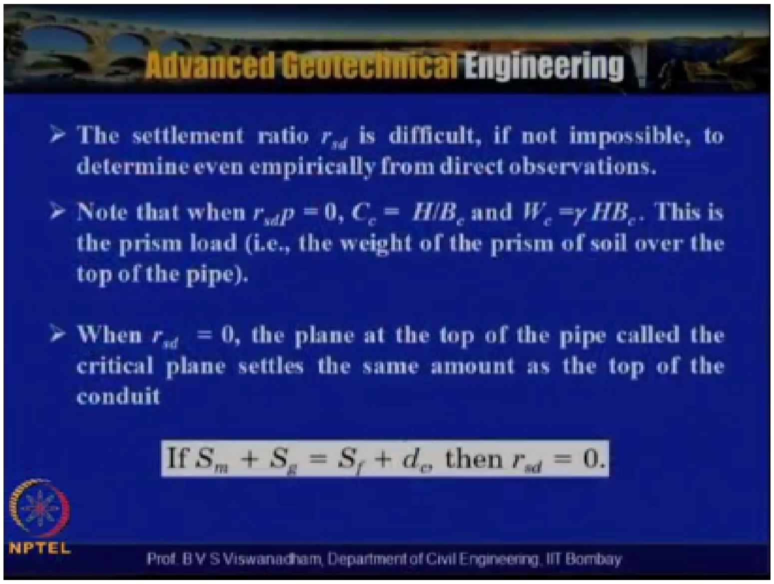

So the settlement ratio r^{sdp} is difficult and if not impossible determine even empirically form direct observations as we discussed here then $r^{sdp} = 0$ Cc = H/ Bc with that Wc = γHBc that means the prism load that is the weight of the soil above over the top of the pipe when $r^{sdp} = 0$ that is nothing but the plane at top of the pipe is called as the critical plane settles as the same out a the top of the pipe that means if Sm + Sg = sf + dc that means that the side soil and the Sf + Sg and Sf +dc.

Then they settle equally the it is called as $r^{sdp} = 0$ if Sm + Sg = SF + dc then settlement ratio will be 0.

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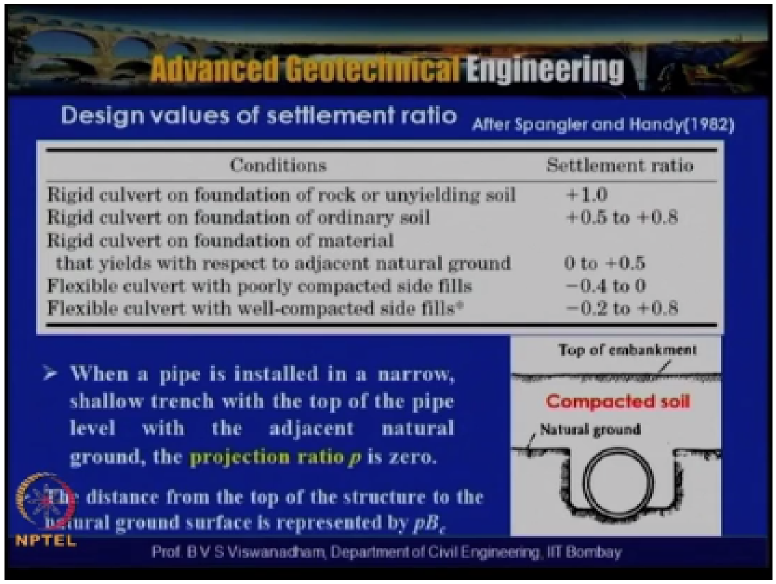

So the here different values of settlement ratios are given r^{sdp} for the rigid culvert on foundation of rock or underlying soil where the settlement ratio is taken as +1 and rigid culvert on foundation of ordinary soil where the settlement ratio is given as + 0.52 + 0.8 and rigid culvert and foundation of a material that yields with respect to the edges and natural ground where the settlement ratio is given as + 0 to 0.5 and flexible converter flexible culvert with purely compacted side fills where the settlement ratio is nothing but – 0.5 0.4 to 0 and flexible culvert with well compacted soil is nothing but - is settlement ratio is nothing but – 0.22 + 0.8.

So he design values of settlement ratio ratios are given here you know for rigid as well as the flexible culverts and the pipe is installed in a narrow shallow trench with the top of the pipe level with the edges and top of the pipe level matches with the natural ground then the projection ratio P is said to be 0, the projection ratio P is said to be 0 that means that when the pipe is installed just at top of the pipe matches with the natural ground surface then the you know the projection ratio is said to be 0.

That distance from the top of the structure is measurable on figure phase is distance from the top of the structure to the natural ground surface is represented by pBc.

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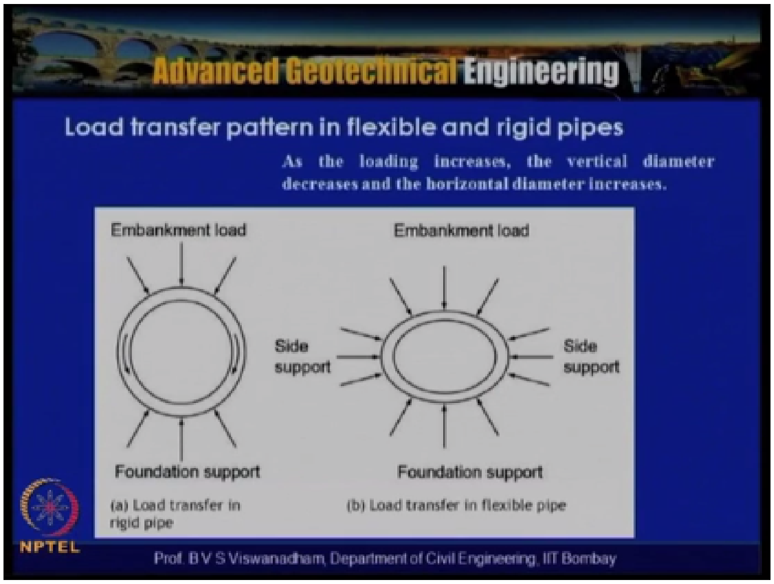

So the load transfer pattern in flexible and rigid pipes is actually shown in this slide and can be seen that the load transfer in rigid pipe is actually internally bond by the pipe itself in case of a flexible pipe as the load increases the vertical diameter decreases and the horizontal diameter lateral diametric increases so you know so it derives support actually from the sides supports so here as the in case of flexible pipes as the you know loading increases it actually you know the vertical diameter decrease and lateral diameter increase.

So they the distinguish should pattern of you know the load transfer machismo is actually shown here in case of rigid pipe which is actually shown in this left hand side of the figure and the right hand of the figure where in it is actually shown a the loading increase the vertical diameter decreases and horizontal diameter increases.

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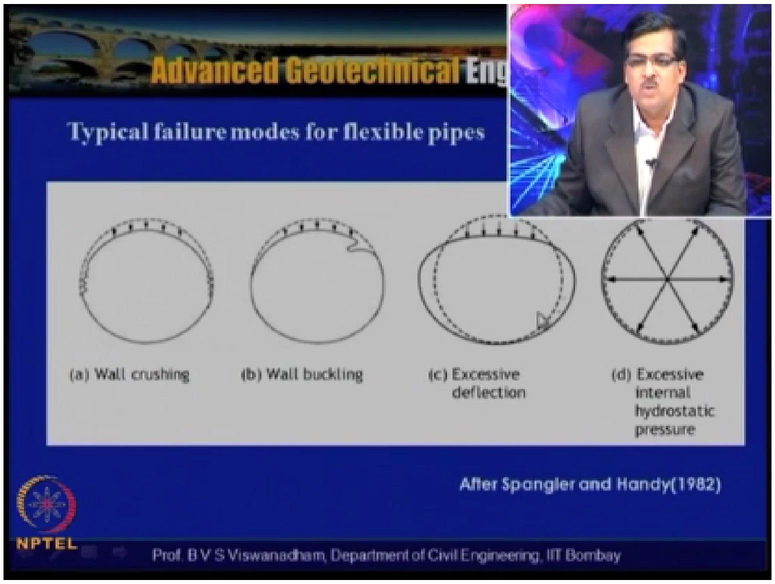

And here the typical failure modes of the flexible pipes is actually shown here and where in we have you know the wall crushing which actually can happen with the furling here which is actually shown here and here the buckling of the pipe which can actually can occur because of the normal form stress buckling of the pipe and excessive defection of the pipe because of the material inherence inherent property because inferior if the material of the pipe which is actually used is inferior.

Then the excessive deflection can come so that actually results in too much decrease in the vertical diameter and increase in the lateral diameters and excessive internal hydrostatic pressures for example if you are actually using some cool water pipe lines under the pressure of the order of 5 bar to 6 bar and because of that if there is a excessive internal hydrostatic pressures the failure planes also failure modes can also can lead to the bursting of the pipe lines.

So the typical 4 difficult failure modes of the flexible pipes are shown here and wall crushing wall buckling and excessive deflection and excusive internal hydrostatic pressure.

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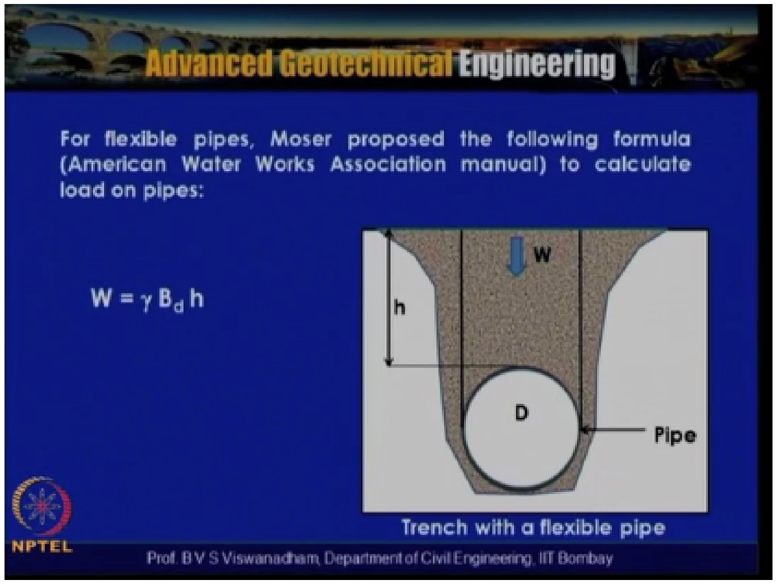

So for flexible pipes most are proposed wit the following expression where W = γBd x h the B is nothing but the breath of the pipe that diameter of the pipe and H is the height of the embarked depth of the pipe.

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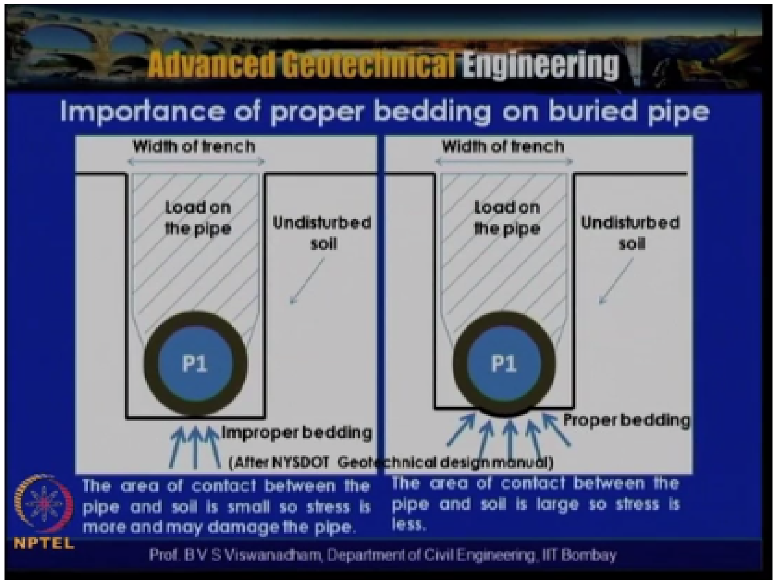

And importance of the proper bundling on buried pipes basically the bedding condition is very much important and the area of the contact between the pipe and soil is so small the stress is actually more and may damage the pipe suppose the area of the contact between the pipe and soil is actually small the stress concentration is actually occurs here and lead to the damage to the pipe so the area of the contact between the pipe and the soil is large so the stress is actually less.

Suppose if we are having an appropriate bedding the proper bedding for the pipe the what will actually happen is that the stress concentration will get reduced here and will not lead to onto ward failures like bulking of the pipes and leading to the nor form stress generation in the pipes and this can actually happen lead to failures in flexible pipes.

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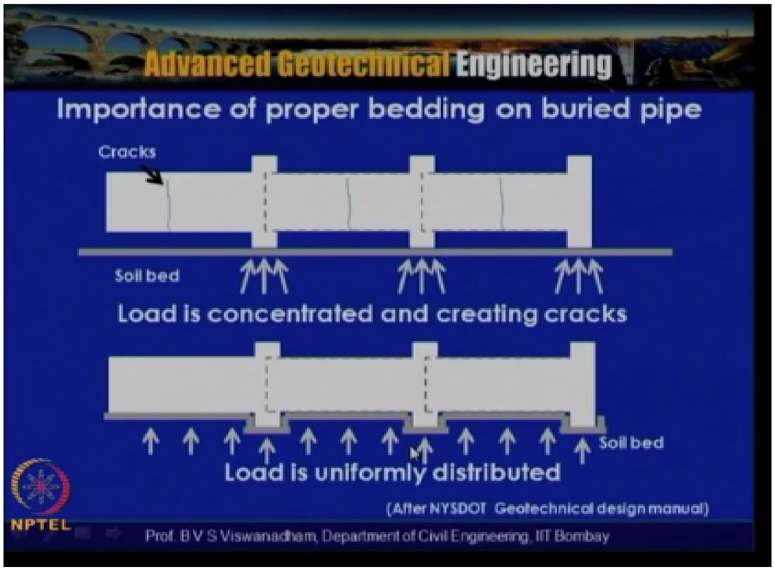

So this importance of the proper bedding on buried pipes for example when we have at the joints and if the joints are actually supported like this there is a possibility that you know this portion actually becomes in on supported and the load is concentrated at this zones and it lead to you know the formation of the cracks and the proper way of doing is that it needs to be properly supported or the proper bedding need to be given so that the load is uniformly distributed and the cracks can be or distress in the pipe can be prevented so in this case here of the because of the improper bedding there is a possibility that the distance in the pipes can be cause.

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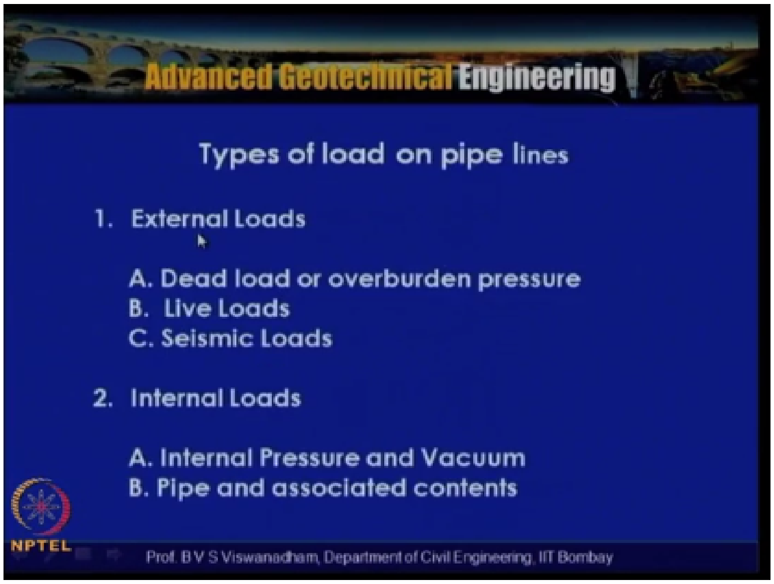

So after having discussed about the you know the different loading conditions of installation the pipes as we have discussed with that the pipes are buried pipes are subjected not only due to the sulphate of the soil but also due to some external loads and internal loads the external loads are nothing but dead load or over burden pressure and live loads nothing but if that area is actually having some vehicular traffic.

Then the vehicular traffic need to be considered and the seismic loads particularly as we have seen that in order to reduce the you know the load of the pipe we actually used no fills and if they are actually saturated you know then in the case of seismic there can be possibility of the pipe flotation and loco fashion which we are actually going to discuss and this the internal loads basically the internal pressure and vacuum and pipe associate and pipe and associated contents.

So that loading on the pipe lines is basically the 2 braid categories one is called external loads and internal loads and another external one of the other external load is also loaded load due to external fluid pressure the load due to external fluid pressure.

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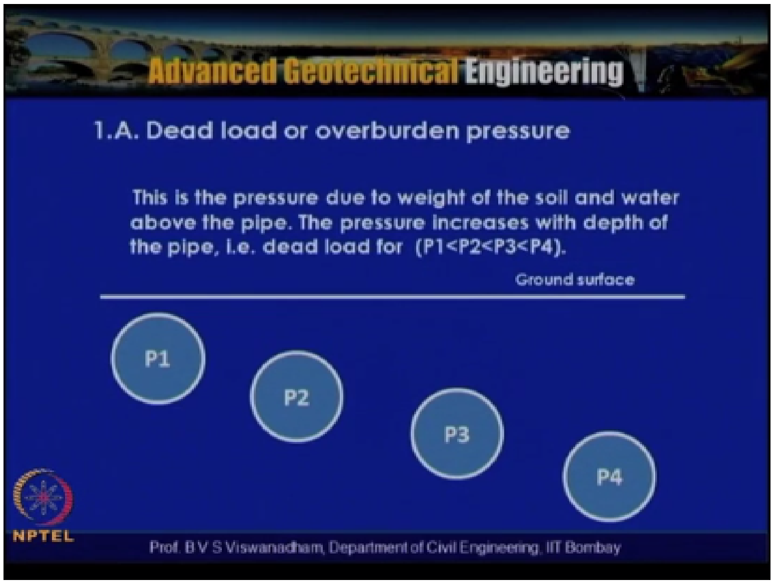

So when you have the dead load or over burden pressure this is the pressure due to the weight of the soil and the water above the pipe so here suppose if we are having a you know let us consider 4 different pipes which are actually placed at different levels the pressure increases with the depth of the pipe that is the dead load of the pipe P1 is actually < P2< P3 < P4 so the pressure due to the weight of the soil and weight of the weight above the pipe so the this is due to the dead load or overburden pressure.

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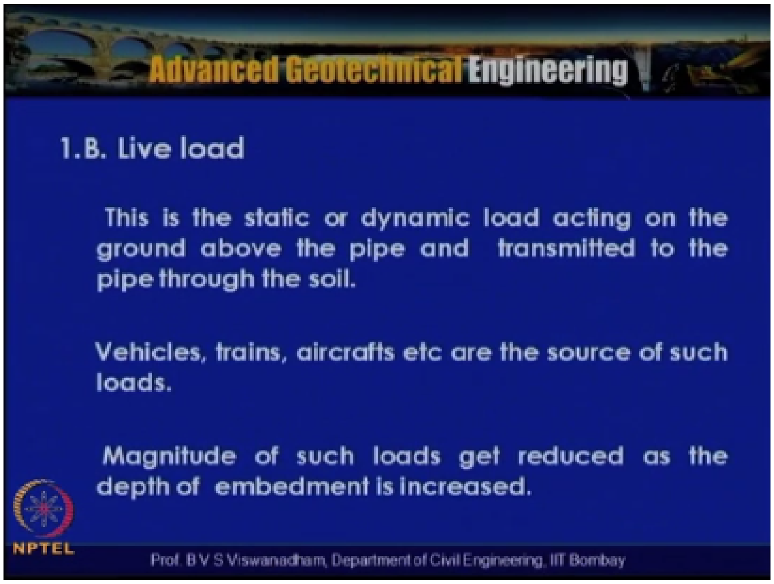

And the livelihood this is nothing but the static or dynamic load acting on the ground above the pipe and transmitted to the pipe through the soil so vehicles in case of railroad traffic the train loading and vehicle loading in case of high way amendment loading 8 crafts in case of a in air payments etc there this force of such loads so magnitude of such loads get reduced at the depth of amendment is increase so what we have actually discussed in this particular lecture is that we have discussed about the different projection conditions.

And we defined the you know the Marston's load theory for flexible pipe condition and where pipe settles more than the surrounding soil in case of rigid pipes surrounding soils settles more than the pipe when these 2 issues are there then we have actually defined a parameter called settlement ratio and depending up on the projection condition we actually have said that $Wc = Cc \times \gamma Bc^{2}$ and then we said that the Cc is actually function of you know H/Bc and the product of γSd and p and k and μ.

And for different projection conditions we actually have deduced the you know the we can calculate what is Cc so with that we can calculate for different position conditions which are actually categories and classified over pipe installation we can actually the prime and most important loading due to the soil and if there after now we will actually try to look into how the external loading like the loading due to some external loading and live load how they can actually effect.

And how these effects can be calculated and further we look import how this pipe defections can be calculated and then subsequent to that we will try to see you know how the issues of pipe flotation and other issue can be addressed and how they can be what are measures to safe guard and prevent pipe flotation in case of a liquefy action continuation.

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