NPTEL

**NATIONAL PROGRAMME ON
TECHNOLOGY ENHANCED LEARNING**

**CDEEP
IIT BOMBAY**

ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 47

Module-6

Lecture-1: Buried Structures

Welcome to lecture series on advanced geotechnical engineering course.

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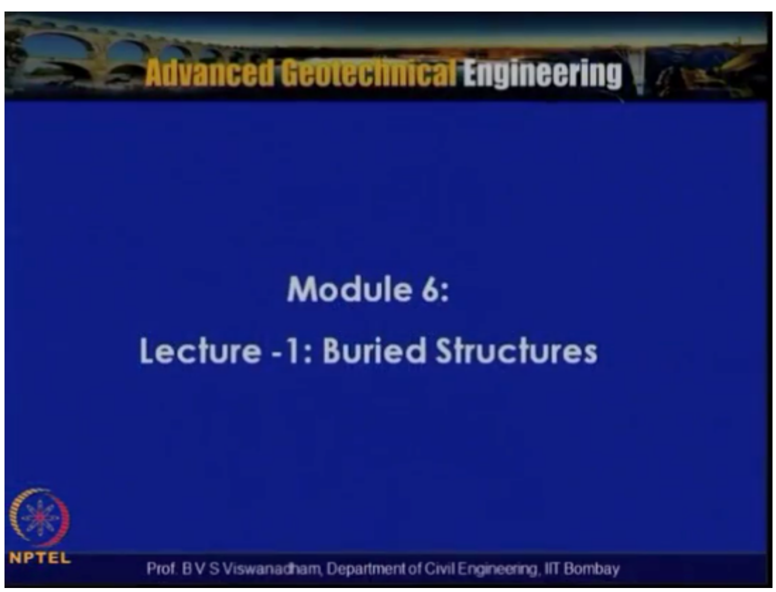

We are into module number 6 which is on buried structures or buried conduits this is lecture 1 so the contents of buried structures or buried pipes in this advanced geotechnical engineering course are load and pipes.

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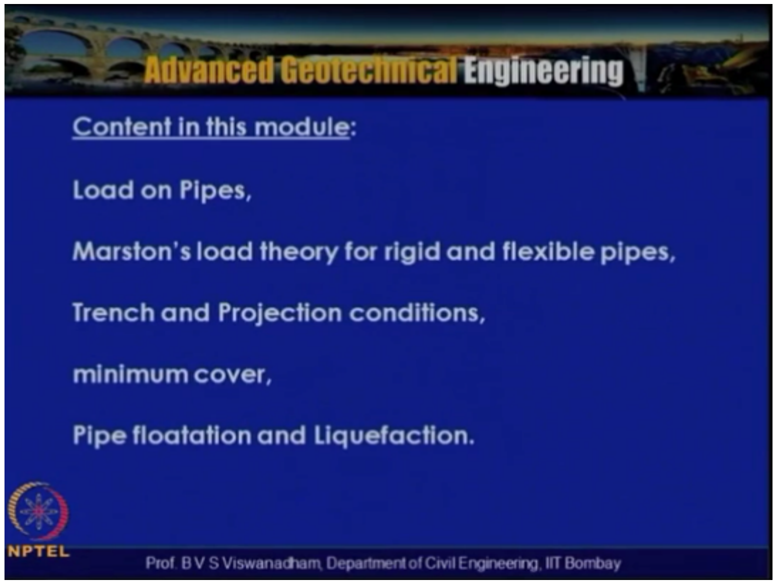

Marston's load theory for rigid and flexible pipers and trench and projection conditions and minimum cover requirement and pipe floatation and liquefaction issues so we will try to looking to the trench and production conditions first and thereafter we will introduce ourselves to Marston's load theory so these buried conduits or the buried pipes are very important form the in the first lecture point of view like many underground.

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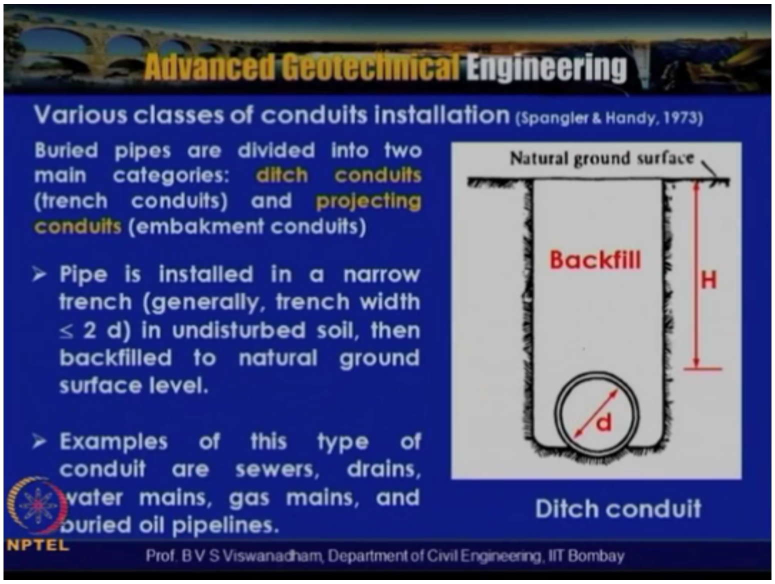

That is which are required nowadays to be embedded below the crowd level and these are off shore as well as on shore so this buried pipelines are divided into two main categories and these are called as ditch conduits that is conduits which are embedded in ditch or in trench and as not all conduits can be put blow the long level so that a some of the conduits will representing out above the ground surface their called embankment conduits or projecting conduits.

So based on the method of installation according to Spangler and Handy 1973 they have been divided principle into two categories, first ditch conduits and projecting conduits so in this particular slide what we have seeing is a trench and with a pipe of certain diameter D that H is the you know height above the pipe from the center line height above the pipe so you can see that this is the natural ground the side walls and this si the back fill so this trenches equated.

The pipe is placed and it is again backfill and then dropped to the natural ground surface so this type of conduits are called ditch conduits and also called trench conduits conditions so the pipes is install in the narrow trench generally that trench between less than or equal to two times the diameter in undisturbed soil then back fill to the natural ground surface.

So pipe is install in a narrow trench and the width of this trench which is BD or B is normally is less than or equal to two times the diameter of the pipe then the back fill to the natural ground surface so examples of this type of conduits are sewers, drains, water mains, gas mains and buried oil pipelines so various classes of conduits installation we are actually trying to look into it and first category we have discussed is that ditch conduits the trench conduits where the pipe is installed in a narrow trench generally the trench would this less than or equal to two times the diameter and in installed in undisturbed soil then this back fill to the natural ground surface.

So examples of this type of conduits are sewers, drains, water mains, gas mains and buried oil pipelines there is also you know another type which is called projecting conduits the projecting conduits are further divided into two classes.

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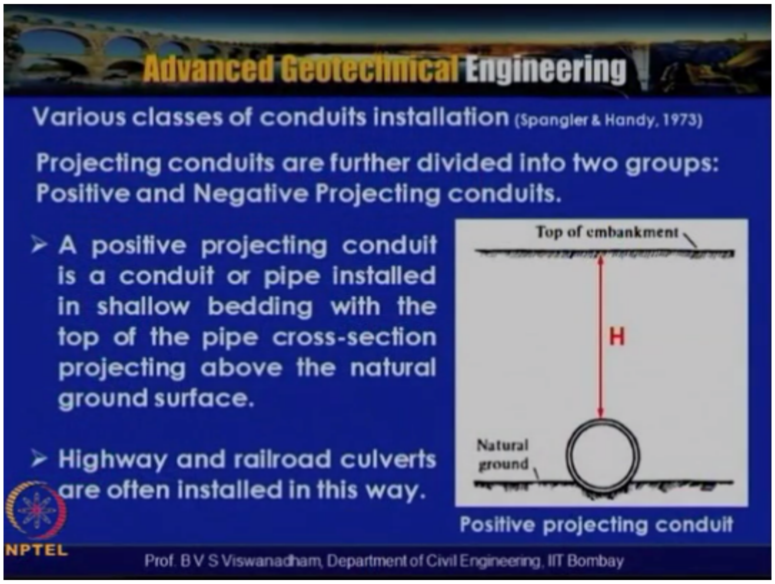

Projective projecting conduits nd negative projecting conduits so in the case of positive projecting conduits it is a conduit or pipe installed in shallow bedding with that top of the pipe cross section projecting above the natural ground surface so if this is the top of the embankment surface that is the fill above the ground then the pipe is actually placed on the ground surface then h is the height above the you know centre of the pipeline so your positive projecting conduit is a conduit or a pipe installed in a shallow bedding with the top of the pipe cross section projecting above the natural ground surface.

This is actually projecting above the natural ground so basically highway and railroad culverts re often installed in this way highway nd railroad culverts are often installed in this way so highway in rail road culverts there basically called as you know the positive projecting conduits so your positive projecting conduit is a conduit are a pipe installed in a shallow bedding with top of the pipe cross section projecting above the natural ground surface.

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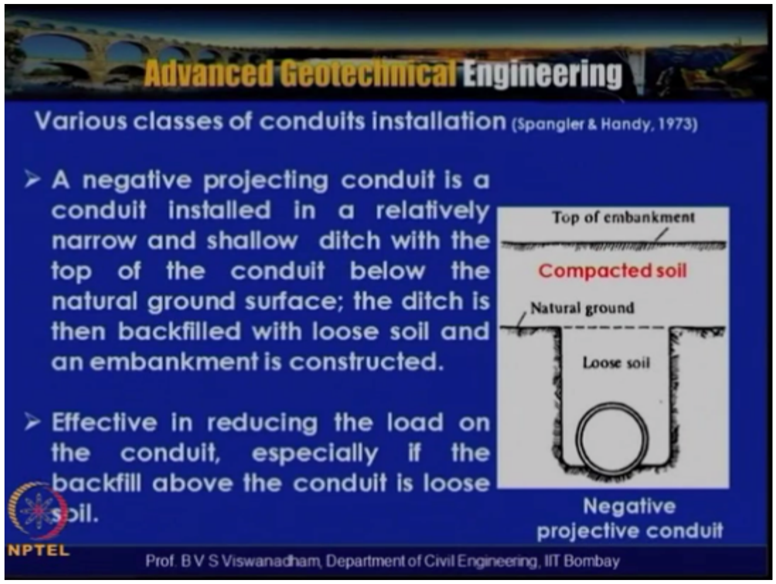

There is also another class of projecting conduits is called a negative projecting conduits a negative projecting conduits is called is conduit installed in a well thoroughly narrow and a shallow ditch with top of the conduit below the natural ground surface and the ditch is then backfilled with loose soil and an embankment is constructed so this is you know negative projecting conduit is literally is installed in a shallow trench.

And the trench is wand which is below the top of the pipe is below the natural ground and the ditch is then backfilled with loose soil and embankment is constructed so this is basically effective in reducing the load on the conduit especially if the backfill above the conduit is backfill above the conduit loose soil so this is effective reducing load on the conduit especially if the effective in reducing the load on the conduit especially if the backfill above the conduit is loose soil.

So they need to projective conduit is basically installed in a narrow nod shallow ditch with the top of the conduit below the natural ground surface and then ditch is then backfilled with loose soil and an embankment is constructed.

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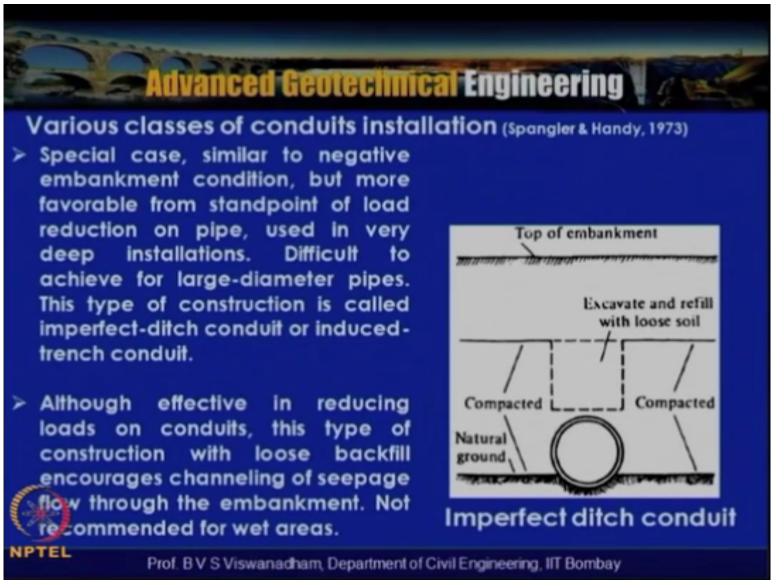

There is also other class of you know in category of conduits which is called imperfect ditch conduit this is a special case similar to negative embankment condition but more favorable from stand point of load reduction on pipe used in very deep installations and difficult to achieve for large diameter pipes and this type of construct is called imperfect-ditch conduit or the induced trench conduits.

So this is a special case similar to negative embankment condition but more favorable from stand point of load reduction on pipe used in very deep installations and difficult to achieve for large diameter pipes and this type of construct is called imperfect-ditch conduit or the induced trench conduits so here these you know here the natural ground is there and the pipe is you know above the natural ground surface the top of the pipe is above the natural ground surface and it is this is this portion of the soil above the right above the pipe is equated nd refilled with loose spoil nd then embankment is constructed.

So all though effective reducing the load on conduits this type of construction with loose backfilled encourages channels of seepage flow through the embankment and not recommended for the wet areas so for example this particularly use of this loose fill encourages basically in reducing the load on the conduits but this type of construction with loose backfilled encourages the channeling of seepage flow through the embankment hence it is not recommended for the wet areas.

So this type of you know the projecting condition of the installation condition of the conduits is called as imperfect ditch condition or induced trench condition this is induced to trench the conduit is that the top of the pipe is above the natural ground and it is you know used in very deep installation and here this portion is equated and refilled with loose soil but because of this you know loose soil they can be you know encouragement of the formation of channel of seepage flow through the embankment hence it is not recommended for the wet areas.

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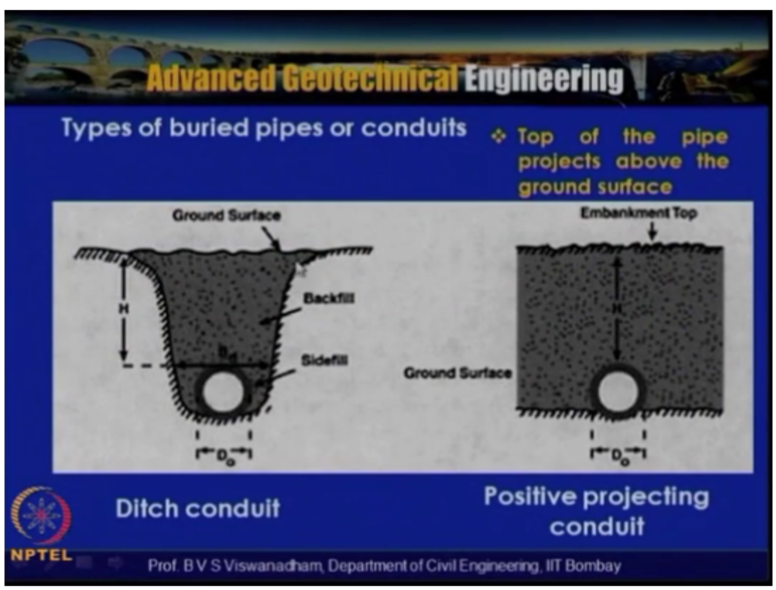

So in this particular slide typically you know types of buried pipes are conduits are shown once again and this is the ditch conduits where this is the you know the side walls and were this backfill with you know certain soil nd this is the ground surface so this is the BD is the breadth of the trench and D_o is the external diameter of the pipe nd this is the backfill in case of a positive projecting conduit were you have the diameter d_o and embankment top is here so the top of the pipe projects above the ground surface.

So here in the positive conduits top of the pipe is projects above the ground surface and demo that the embankment constructions will happen.

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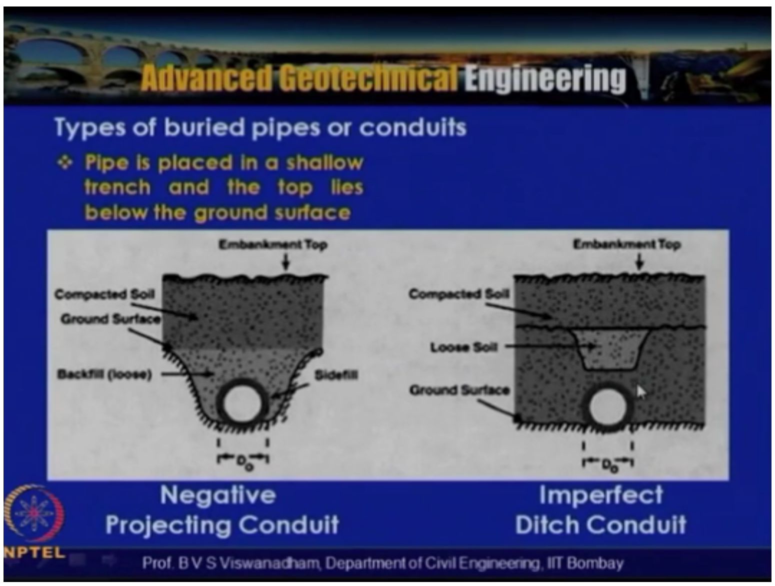

And negative projecting conduit the pipe is placed in a shallow trench and the top lies below the ground surface the top of the pipe lies below the ground surface so this is the negative projecting conduit and this imperfect ditch conduits is gain shown here a schematically were you have got top of the pipe above the natural ground surface and a portion which is actually you know filled with loses soil basically to reduce the load bon the conduits.

And then embankment is constructed on the top so this type of construction of conduit is called installation of conduit is called imperfect ditch conduit.

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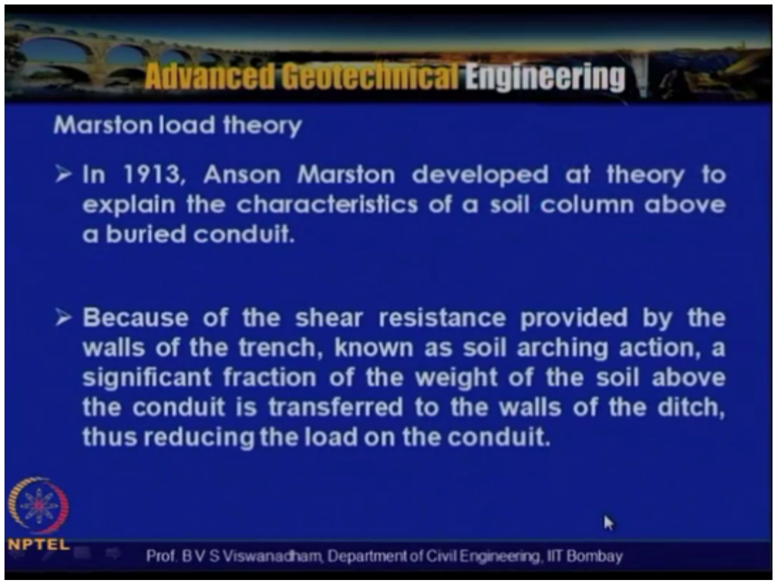

So we have seen different types of you know the conduits installations nd accordingly Marston as actually proposed in a load theory in 1913 so in 1913 Anson Marston developed at theory to explain the characteristics of soil column above the buried conduit so because of the shear resistance provided by the walls of the trench known as the soil arching so we need to understand what is this soil arching, soil arching is a phenomenon in which transfers the forces or stresses to the zones.

So here significant fraction of the weight of the soil above the conduit is transferred to the walls of the ditch as reducing the load on the conduit so because of the because of the shear resistance provided by the walls of the trench known as the soil arching action a significant fraction of th weight of the soil above the conduit is transfer to the walls of the ditch and then reducing the load on the conduit.

So the we have this soil arching phenomenon is actually is visible in number of you know application in geotechnical engineering namely in retaining walls and in buried conduits so with reference to from buried conduits point of view will try to see what is the soil arching and there are two types of soil arching one is called active arching and passive arching.

So the Marston load theory will introduce ourselves and then see that how the you know the load transfers on to the pipe is there can be computed for a given condition.

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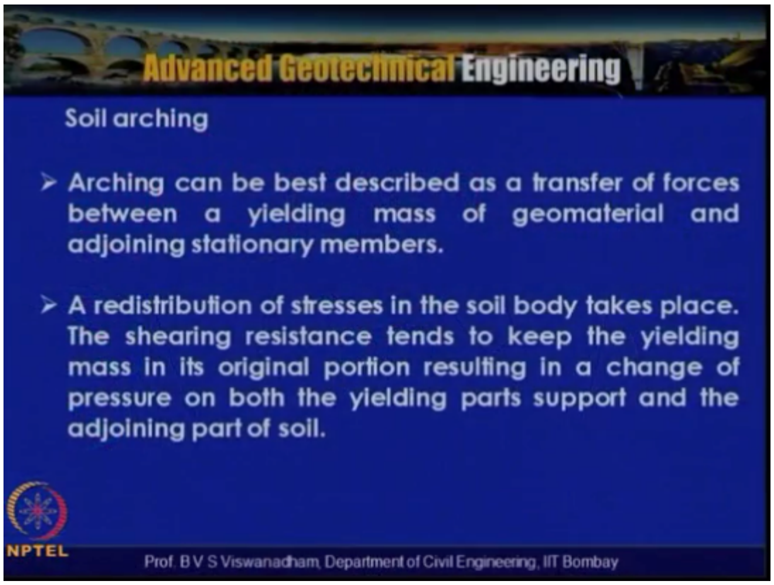

So now let us try to understand about the soil arching, soil arching can be you know the best described as the transfer of the forces between yielding mass of geo material and adjoining stationery members so arching can be best described as a transfer of forces between yielding mass of geo material and adjoining stationery members.

So stationery members are nothing but non yielding zones in aces of buried conduits it is you know the side walls so here redistribution of stresses in the soil body takes place so the shear resistance tends to keep the yielding mass in its original position resulting in change of pressure and both the yielding parts you know support and then adjoining part of the soil so here redistribution of stresses in the soil body takes place because of this part space on the arching and the shear resistance tends to keep yielding mass in its original position resulting in change of pressure and both the yielding parts support and then adjoining part of the soil.

So this top of the soil arching we have also actually discussed in when we are discussing about using pipes and we said that then pipes are paced very close to the each other with center to center distance within these slope at in optimum location within the slope then we said that the part spacing of arching is visible and when the pipes are placed on the part like sc=ad then d is the diameter of the you know pipe then we said that the pipes will behave like that individual pipes and then visible to your participation of arching marginable or negligible.

So similarly we have the phenomenon here that when the trenches narrow and when the fill is actually try to settle and then redistribution of the stresses takes place mad the shear resistance tends to keep the tends to keep the yielding mass in its original position resulting in change of pressure and both the yielding parts support and then adjoining part of the soil.

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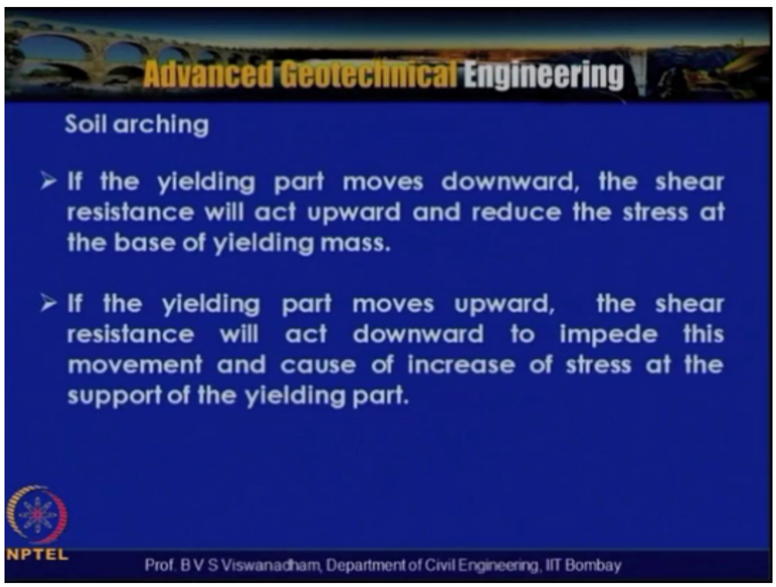

If the yielding part moves downward that means that the soil above the conduit the shear resistance will act upward and reduce the stress at the based on the yielding mass so what will happen is that if the yielding part moves downward means that the soil above the conduit the shear resistance will act upward and reduce the stress at the based on the yielding mass.

So what will happen is that if the yielding part moves downwards the shear resistance will act upward and reduce the stress at the based on the yielding mass if the yielding part moves upward suppose if the yielding part moves upward the shear resistance will act downward to impede this movement and cause of increases of stress at the support of the yielding part if the yielding part moves upward suppose if the yielding part moves upward the shear resistance will act downward to impede this movement and cause of increases of stress at the support of the yielding.

So this causes to this stress increases this cause to the stress increases at the support of the yielding part so with the yielding part moves downward the shear resistance will act upward and reduce the stress at the based on the yielding mass so this will actually happen in the narrow you know the trench conduit and ditch conduit condition if the yielding part moves upward the shear resistance will act downward and to impede this movement and cause of increases of stress at the support of the yielding part.

So consider as we said that the two types of arching one is celled active arching and other one is called as passive arching so here if the structure is compressible.

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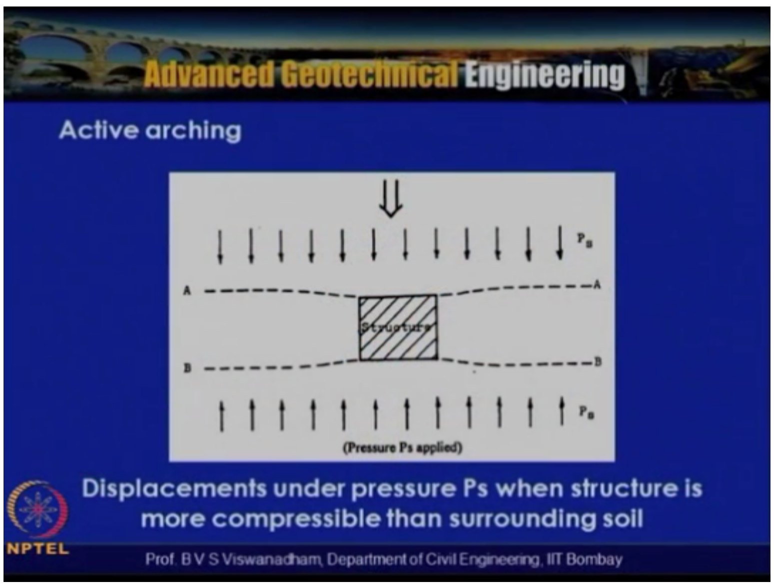

So the displacement under pressure Ps when the structure is more compressible than the surrounding soil so this is a typical structure which is consider and this is the surrounding soil so the pattern of displacement t plane AA and BB will like this and displacements and pressure Ps when the structure is more compressible than the surrounding soil you can see there the soil in this portion will undergo in settlement and so this is the displacement patterns and the pressure when the structure is or compressible than the surrounding soil.

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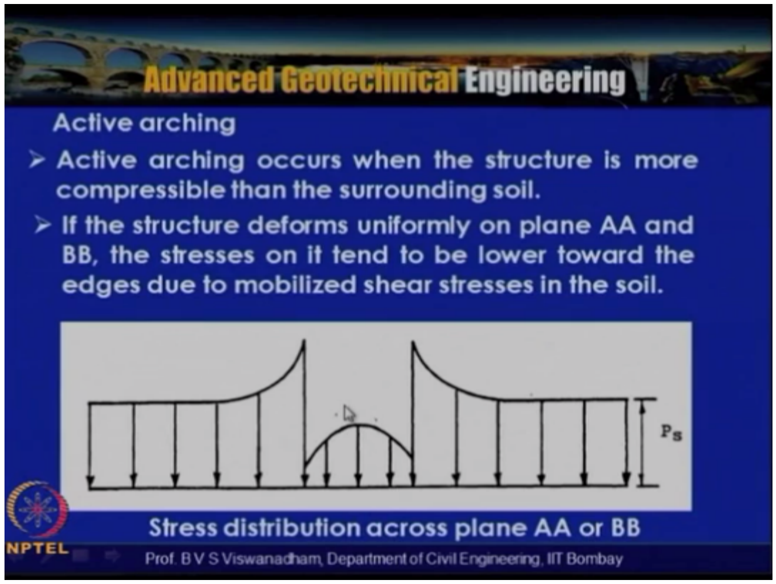

So in this case active arching occurs when the structure is more compressible than this surrounding soil so in active aching occurs when the structure is more compressible than the surrounding soil so if the structure deforms uniformly on plane AA and plane BB the stress on it tend to be lower toward the edges due to mobilized shear stresses in the soil.

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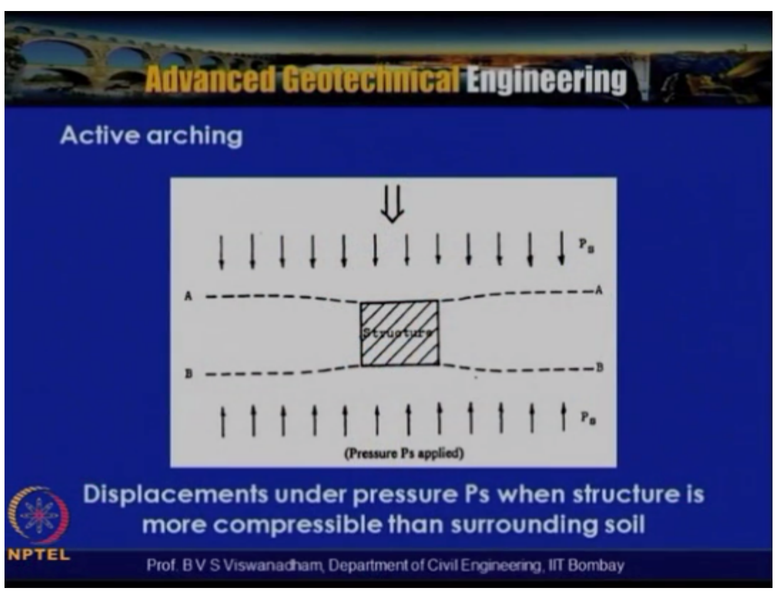

So if the structure depends like this and the structure as more compressible than the surrounding soil.

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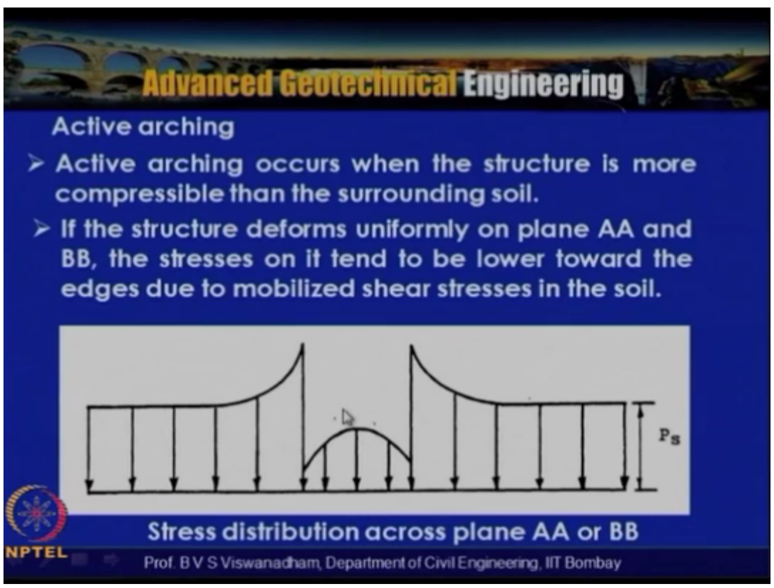

Then at plane AA or BB a stresses on its tends to be on the lower towards the edges due to the mobilized shear stresses in the soil so because of the mobilized shear stresses the stress will be lower and then you can see that surrounding reads that is the non yielding portions or actually receiving the higher stresses so this is you know terminology of you know defined as the active arching, active arching occurs when the structure is more compressible than the surrounding soil.

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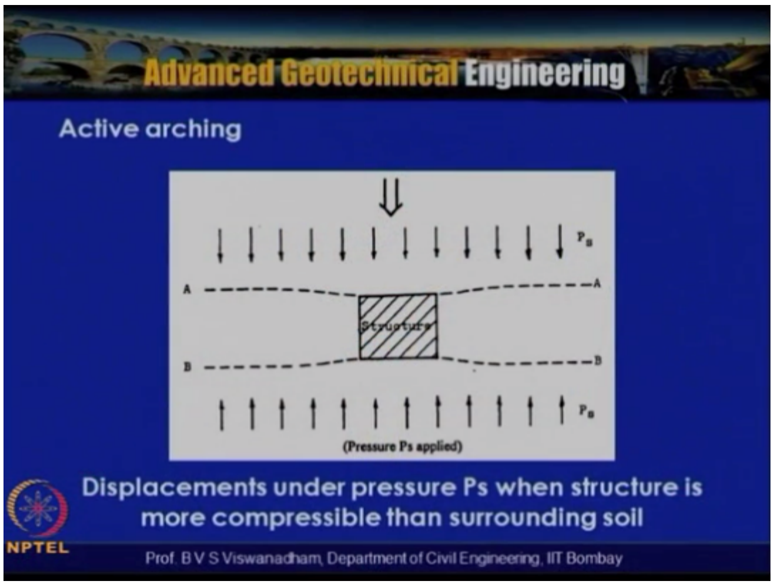

Now as we said the another type of arching is passive aching nd the pattern of discuss will be like this in case of passive arching where the structure is less compressible than the surrounding side when the structure is less than compressible than the surrounding soil so that means that here theses settlements in this zones will be less and the surrounding soil actually A is 1 that means that there will be differential settlements here.

There will be differential settlements here and there will be you know there will not be nay settlements here so this is the displacement pattern under pressure Ps when the structure is less compressible than the surrounding soil this structure is less compressible than the surrounding soil .

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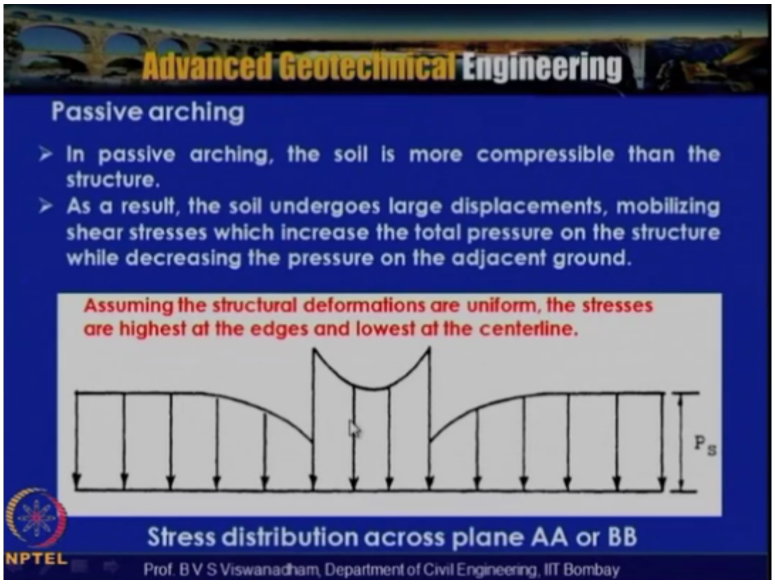

So in case of passive arching the soil is more compressible than the structure so passive arching occurs when the soil is actually more compressible than the structure so as a result the soil undergoes large displacements at mobilization of shear stresses which increase the total pressure on the structure while decreasing the pressure on the adjacent ground.

So as result what we can see is that the soil undergoes large displacements because of the reduction in the occurrence of the settlement you can see that mobilizing you know the shear stresses which increase the total pressure both structure while decreasing the pressure on the adjacent ground so this is the typical stress distribution across plane AR may be where you can see that and at the edges you see that the stresses are highest.

And the lowest in the centre line so this is because as the zooming that the structural deformations are uniform being you know in the sense that rigid compare to you know the surrounding soil the stresses are highest in the edges and lowest on the centre line so you can see that this distribution is because the structural deformation are uniform being rigid compare to surrounding soil.

The stresses are highest at the edges the edges in the lowest at the centre so in the passive arching the soil is actually more compressible than the structure and assuming that the structural deformations are uniform the stresses are highest at the edges and lowest at the centre line so as a result that you can see that the soil undergoes large displacements mobilizing shear stresses which increase the total pressure on the structure while decreasing the pressure on the edges on the ground.

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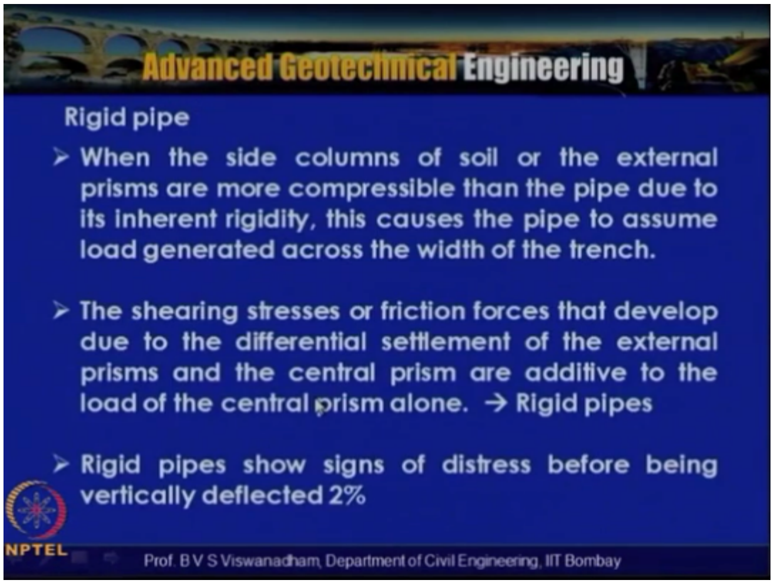

So after having seen active arching and passive arching we said that the active arching occurs when structure is you know under more flexible, more structure is in case of passive arching the soil is more compressible than the structure in case of active arching soil is you know structure is more compressible than the surrounding soil okay.

So when the rigid in case of rigid pipe now were you can see that with the two types will come across that is called as rigid pipes and flexible pipes and rigid pipes at the side column of the soil are external prisms are more compressible than the pipe due to its inherent rigidity and this causes the pipe to assume load generated across the width of the trench.

So when the sides columns of the soil are external prisms are more compressible than the pipe due to its inherent rigidity and this causes the pipe to assume load generated across the width of the trench so just of you seen passive arching you know the soil is more compressible than the structure so similarly here when the side columns of the soil are external prisms are more compressible than the pipe due to its inherent rigidity and this causes the pipe to assume load generated across the width of the trench.

And the shearing stresses are the friction forces that develop due to differential settlement of the external prisms and the central prism of soil are editing to the load of the central prisms alone so this is defined as rigid pipes so rigid pipes show the signs of the stress before being vertically reflected at 2% of the diameter that is rigid pipes show as size of the stress before being vertically deflected by 2% of the diameter.

So in rigid pipes when the sides of soil columns of soil are external prisms are more compressible than the pipe due to its inherent rigidity and this causes the pipe to assume load generated across the width of the trench and the shearing stresses are the friction forces that develop due to differential settlement of the external prisms and the central prism of soil are editing to the load of the central prisms alone.

So this condition this type of pipe is called rigid pipes and rigid pipes are showed the signs of the stress before being vertically reflected at 2% of the diameter.

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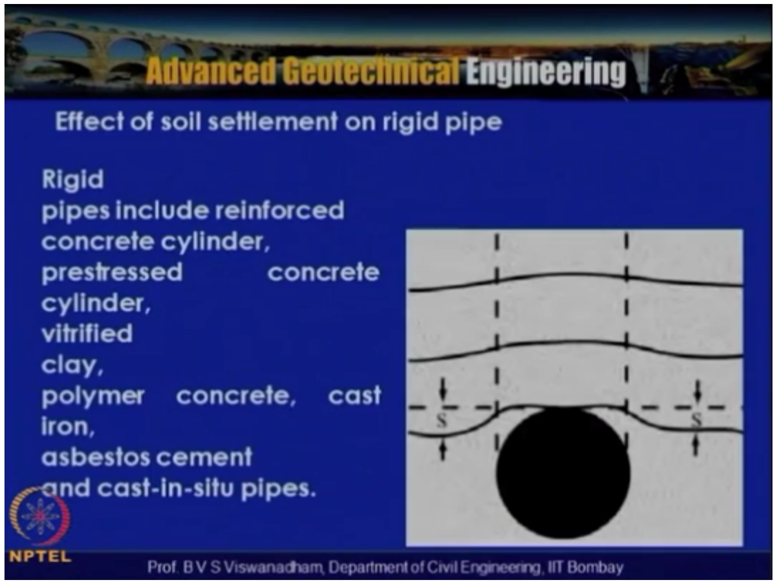

The typical rigid pipes include reinforce concrete cylinder prestressesd concrete pipes and vitrified clay and polymer concrete and cast iron asbestos cement and cast iron asbestos pipes so what we can see is that in effect of the soil settlement will be being the structure is rigid is here so this is type of passive arching condition this is type of passive arching condition what we discussed the surroundings soil here undergoes the differential settlements and where here because of the inherent rigidity the structure will not undergo any movements.

But the because of this you know settlements are uniform the stresses will be higher at this point and at this point and the asbestos centre will be lower so this type of situation is very close to rigid pipe you know embedded in the certain depth in the soil is very similar to this passive arching phenomenon so typical rigid pipes include reinforce concrete once re made up of prestressesd concrete pipes and vitrified clay and polymer concrete and cast iron asbestos cement and cast iron asbestos pipes.

This are all you know rigid pipes but effect of the soil settlement of rigid pipe is actually shown here the surrounding soil is actually settles undergo settlement here and because of this inner and this portion is actually not does not undergo any movement so you can see that both sides it undergoes surrounding soil prisms undergoes movements and this particular portion will not actually undergo any settlement because of the rigidity of the pipe.

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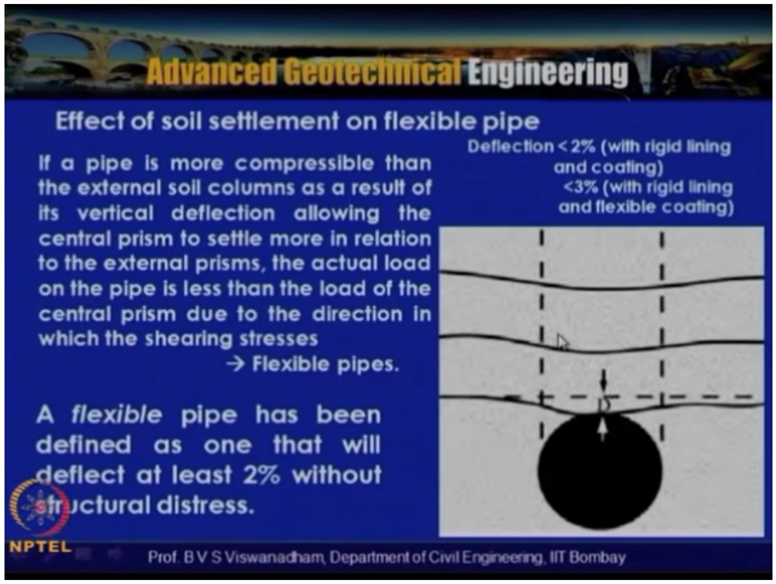

Now consider the flexible pipe if the pipe is more compressible than external soil columns as a result of vertical deflections allowing the central prisms to settle more in relation to external prisms then the actual load on the pipe is less than the load of the central prisms due to the direction in which the shearing stress are acting.

So this pipe this step of pipes are called flexible pipes so you can see that the settlement D at this portion settlement D at this portion the soil undergoes in this portion undergoes different settlement and the surrounding soil does not undergo any you know the movements are middle to or less compared to you know in the zone which is actually above the pipe.

So if the pipe is pos this condition is very close to active arching condition what we have seen a two arching condition were the surrounding soil is actually more compressible you know the this structure is actually more compressible than the surrounding soil so if the pipe is more compressible than external soil as a result of the vertical deflection allowing the central prisms to settle more in relation to external prisms then the actual load on the pipe is less than the load of the central prisms due to the direction in which the shearing stress are act and this condition is called flexible pipes.

So if flexible pipe has been defined as the one that will deflect at least 2% without the structural distress so if generally there is also another definition for the flexible pipes is a flexible pipes as been defined as one that will deflect at least 2% without the structural distress and the deflection is limited for less than 2% with rigid line and coating and if you are having rigid line with flexible coating then it is 3% the deflection is to be limited less than 3% of the diameter with rigid lining and flexible coating and if you are having rigid lining and coating then it is effected on the deflection will limited only to less than 2%.

So the flexible pipe condition is acting arching condition and rigid pipe condition is the passive arching condition in case of flexible pipe the active arching condition thus pipe the soil portion above the pipe undergoes differential settlements compare it to the adjacent soil prisms and because of this what will happen is that load acting on the buried pipe will be less they depending upon the because of the you know shear distress offer by the side walls on the both sides of the pipe.

That is this portion because of this what will happen is the shear distress will act in this direction and the load is actually a portion there is the load which is actually imposed on the quantity will be less so if the pipe is more compressible than the external soil columns as a result of vertical deflection along with central prisms to settle more in relation to the external soil the soil in the external prisms.

The actual load on the pipe is less than the load of the central prisms due to the direction which the shearing stresses are acting.

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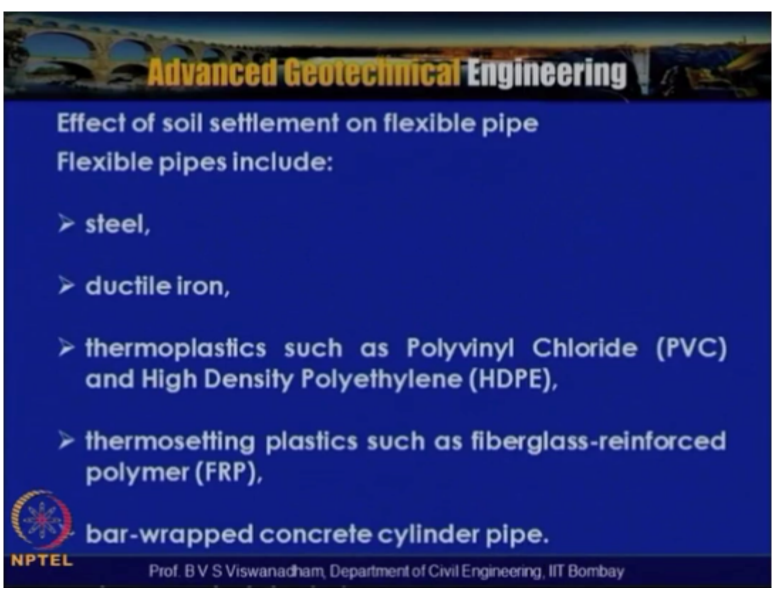

So the flexible pipes for examples include steel pipes and ductile iron pipes and thermoplastics such as Polyvinyl chloride and HDPE pipes high density Polyethylene pipes and thermosetting plastics such as fiber glass reinforced polymer FRP pipes and bar wrapped concrete cylinder pipes so for examples for flexible pipes which are actually used for making this flexible pipes includes steel, ductile iron, thermoplastics such as Polyvinyl chloride and HDPE pipes high density Polyethylene pipes and thermosetting plastics such as fiber glass reinforced polymer FRP pipes and bar wrapped concrete cylinder pipes.

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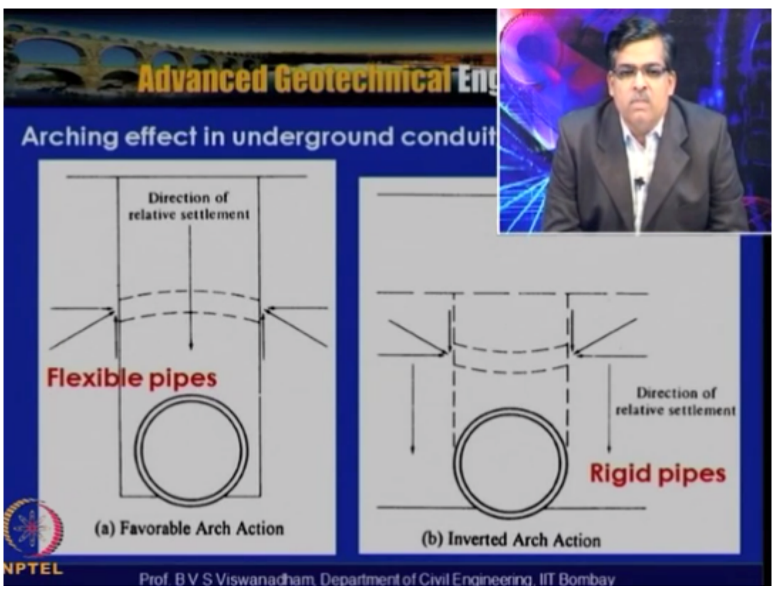

Now here the typical favorable art conditions are actually shown arching effect is underground conduits you can see that here this is a flexible pipes so where the direction of the relative settlement will be here in this direction the resistance from this side walls actually act upwards so because of this load acting in the central position will be less so in this case you know arch action.

And this is phenomenon in rigid pipes were the surrounding soils actually settings more compare to the soil above the pipe so this is inverted arch action which also there in the rigid pipes and favorable arch action there will be there in the flexible pipes.

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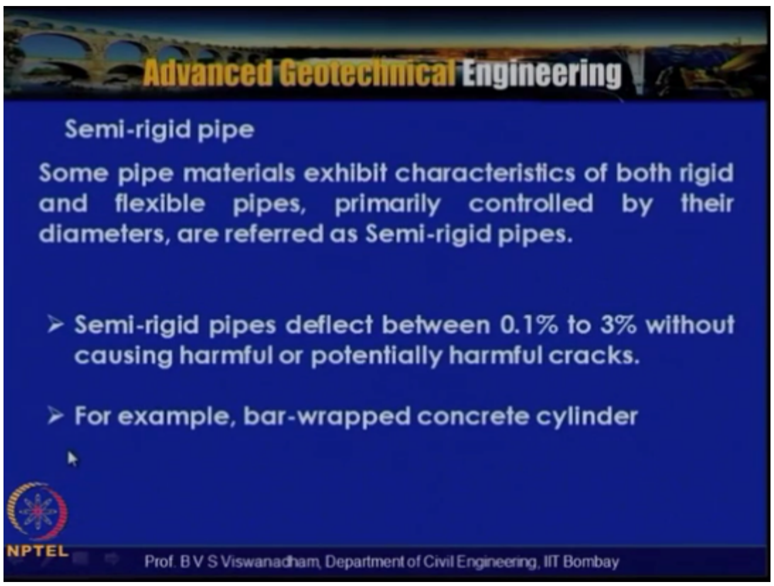

So we have seem that flexible pipe nd rigid pipe in the flexible pipe were in the soil above the pipe will undergo settlement and o because of this the shear resistance participation of active arching and or we can say favorable arching there is the reduction of the load coming on to the pipe so the buried conduits will experience the less load so there is also rigid pipes and then we also said that there is one more category called semi-rigid pipes.

Some pipes materials exhibit characteristics of both rigid nd flexible pipes primarily control by the diameters and there basically referred as semi- rigid pipes so semi-rigid pipes reflecting between 1% to without causing harmful or potentially harmful cracks for example bar-wrapped concrete cylinder pipes is actually is an example for the semi-rigid pipes so some pipe materials exhibit the characteristics of both rigid and flexible pipes and primarily controlled by the diameters. And basically they referred these these types of pipes are referred as semi-rigid pipes.

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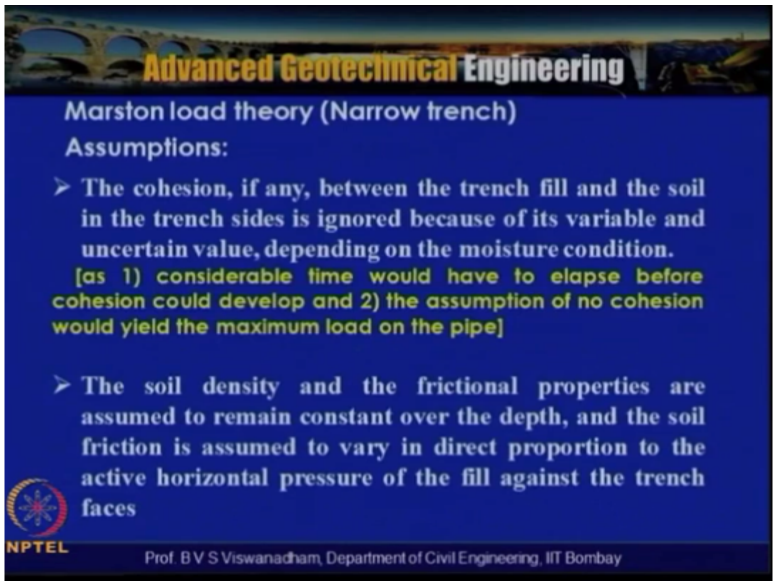

So in going to understand about Marston load theory for narrow trenches and let us look into the assumptions which are put forwarded here the cohesion if any between the trench fill and the soil in the trench side is ignored so the primary the cohesion if any between the trench fill and the soil in the trench sides is ignored because of its variable and uncertain value depending upon the moisture condition.

So the ignorance of this cohesion also would have you know in conservative side basically so that you know we will actually calculate more load on the pipe okay so as one is that you know the considerable time would have to be elapsed before cohesion would allow and second thing is that assumption of cohesion would yield the maximum load on the pipe.

Thus what we are discussing but assumption of low cohesion will yield with maximum load on the pipe so the cohesion if any between the trench fill and the soil in the trench sides is ignored because of its variable and uncertain value depending on the moisture condition and the oils density and the friction properties are assumed to be remain constant and the soil friction is assumed to be vary with the direction proportional to the active horizontal pressure we feel against the trench faces.

So the soil density and the friction properties are assumed to be remain constant over the depth and the soil friction is assumed to be vary in the direction proportional to the active horizontal pressure we feel against the trench faces so we have the pipe is embedded in a narrow trench we have the two side faces when we are actually taking per unit length of the pipe.

So the cohesion is ignored the ignorance of the cohesion has you know as because one is that the reason for ignoring the position is that the considerable time we have to elapsed before the cohesion could go away and second thing is that ignorance of the cohesion between the conservative assumption as a low cohesion would yield the designed for that type of load which is coming from the soil above the pipe.

And the soil density and the friction properties are assumed to be remain constant over the depth and the soil friction is assumed to be vary in the direction proportional to the active horizontal pressure we feel against the trench faces.

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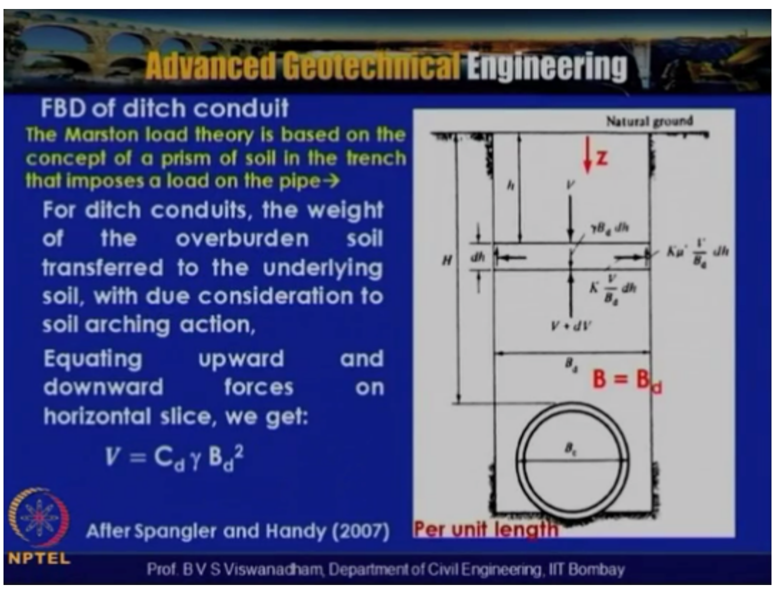

So in this particular slide you are free boding slide diagram of the ditch conduits which is actually shown here a type of the diameter external diameter BC and are conduit of BC and internal diameter let us say a small d and width of the trench is indicated here as BD but for the terminology we can also write BC=BD and so net Z is the depth form the natural ground surface so this is the ditch conduit condition so Marston load theory based on the concept of the prisms of the soil in the trench.

That impose load on the pipe so ditch is the height you know above the centre of the pipe and B=Bd and so these are the you know the side wall prisms and this is the portion of the soil above the soil within the prisms which is above the pipe and this is called the bedding of the pipe you know and then consider the per unit length so the Marston load theory is based on the concept of the prisms of the soil in the trench that imposes the load on the pipe.

So this is basically for the ditch conduit the weight of the warm soil transfer to the underline soil with due consideration to the soil arching action so equating upward and downward forces we get $Cd*\gamma*Bd^2$ so how we got is nothing but we have taken a thin horizontal slice of having thickness small dh at a depth dh below the ground surface or it depth Z below the ground surface.

And when this the sulfate of this soil which is nothing but γ that is unilateral soil that fill into the trench after installing the pipe γ*bd*dh so bd*dh*1 is that volume that is the perimeter length into γ is the weight of the soil weight force acting like this now at a given portion at a given depth here what you can see is that V is the vertical load acting over an area that is nothing but bd*1 so V/bd is the vertical stress into k that is nothing but the k is nothing but the coefficient of earth pressure which is you know the ratio of the latent pressure that is horizontal pressure to vertical pressure.

So k*vertical stress into dh active or a small length that is the dh*1 that is the force acting you know acting on the normal force acting on the side walls face so we can get the frictional force when this mass goes downwards k*μ'or μ into v/dh is the countering shear resistance or shear force.

So this are the two sides we actually have this shear forces and here the normal force acting at a given depth so how we have got this one is nothing but this is the v/bd is the vertical stress v/bd*1 into k is the horizontal stress into dh into 1 is the horizontal force and then into multiplied by μ' you will get the you know the friction force acting along the shear force acting towards this direction this side direction nd this direction.

Now we taking the equilibrium of σf=0 what we get is that we get a differential equation and then once e solve that one nd for this condition then we get this v=cd*γ*bd^2.

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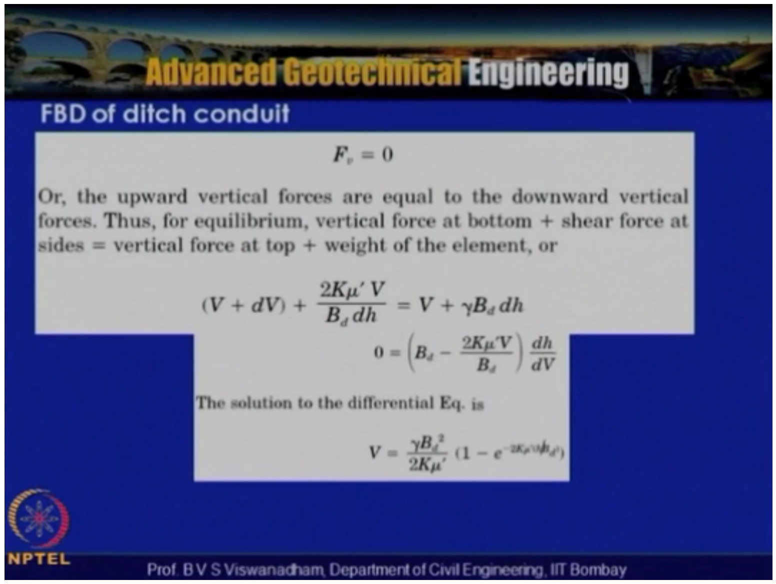

So this is what actually described here for σfv=0 taking upward vertical forces or equal to the downward vertical forces so for equilibrium vertical force at the bottom plus shear force at the sides is equal to vertical force at the top plus weight of the element on the slice so vertical force at the bottom that is the bottom of the slice and shear force at the sides is equal to vertical force at the top and weight of the element.

So that is the vertical force at bottom that is nothing but v+∂v and shear forces at sides that is because of two sides are there it is multiplied by 2*k*v/bd dh*μ' so two sides of there so multiply by 2 is equal to v that is the stress acting on the top of the slice horizontal slice plus the sulphate force that is γbd*dh by simplifying what we get is that 0 is equal to bd-2kμ'v/bd*dh/dbv so this is basically the solution of the differential equation and the solution will actually yield to v=γbd^2/2kμ'*1-e -2kμ'/h/bd h/bd.

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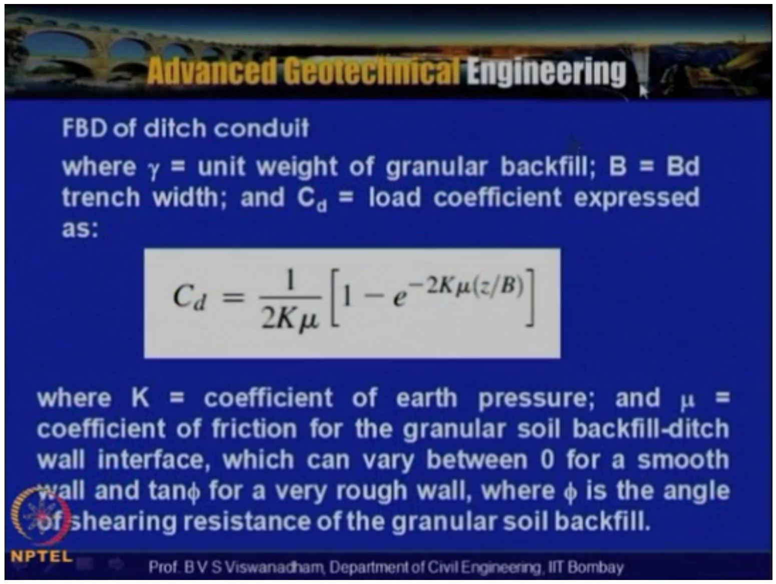

So this expression for w were b=γcd bd^2 so this is given as you know the cd is nothing but 1/2kμ*1-e -2kμz/b were k is nothing but the coefficient of earth pressure and μ= coefficient of that pressure and μ is the coefficient of friction for granular soil back fill ditch wall interface that is the coefficient of the friction of the granular soil backfill and ditch wall interface and which can vary from 0 for a smooth wall and tan Ø for a rough wall were Ø is the angle of shearing resistance of the granular soil fill.

And γ is nothing but the unit weight of the granular backfill B=Bd trench width and Cd is the load coefficients so this is the load coefficients so this if we use V=cd γcd bd^2 if you are able to get the we can actually get the load on the pipe so this cd we can obtain by 1/2k μ[1-$e^{-2k\mu(z/b)]}$ when z= h then you know it will be on the top of the pipe that is the you know.

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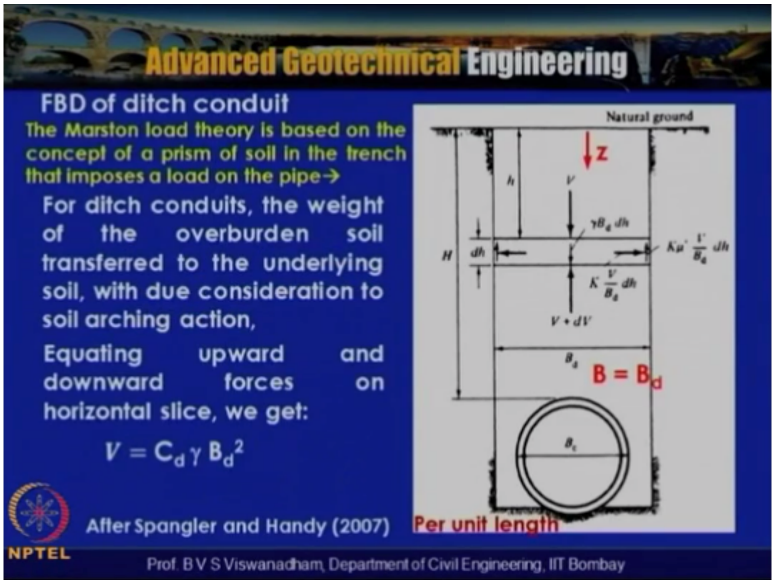

If you consider this portion when z=H we will get the load coming on the stress coming on this particular portion in kilo Newton per meter.

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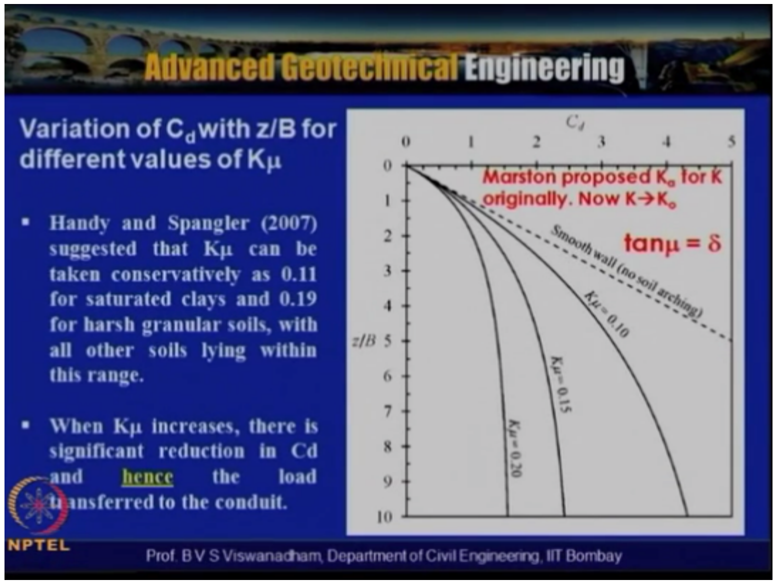

Now let us look variation of cd with z/b for different values of Kμ so what we said is that this particular graph which is actually shown were cd is plotted on the x axis from 0 to 5 that is the load cohesion so z/b which is z=0 at the top of the that is the ground surface and for low arching no soil arching the smooth wall we can see that you know the this particular tends to the somewhere here.

But when there is you know kμ=.1 Kμ=1.5 and μ=.2 then you know you can see there kμ is increasing there is decrease in the cd value with increase in kμ value there is decrease in the kμ value there is decrease in the cd so in case of you know this variation of cd with z/b for different values of kμ Handy and Spangler in 2007 they suggest that kμ can be taken conservatively as .11 for saturated clays where there is the multiplication of k initially Marston proposed ka that is the rankings activate pressure condition for k.

This is originally proposed by Marston now it is actually you know convenient to consider $k=k_o$ where k_o is equal to you know coefficient that is for like by using Jacky's formula it is 1- ψ Ø and where Ø is the friction angle and it is also convenient to consider tan μ=∂ where ∂ is the interface friction angle between back fill soil and as well as the side wall soil in the side wall so Handy and Spangler suggested that kμ can be taken conservatively as .11 for saturated clays and .19 for the you know the granular soils with all other soils they like within this range.

That means that for most of the soils they far within range that is kμ factor will actually fall in between .1 to .2 when the kμ is increasing there is the significant reduction in cd hence the load transfer to the conduit so when cd you know decreases that is one kμ increases then there is the decrease in the cd value the significant reduction in the cd value can be seen and that is that imp0lies that load on the conduit also reduces,.

So here what we have seen is that w that is v=γcd you know bd^2 with that what actually said is that when a smooth wall is there no arching is taking place then this is the situation so when we have you know large width of the trench and when there is a no participation of arching then you know no soil arching takes place.

But for most of the soils were kμ falls within between the .1 to .2 were kμ increases when the significant reduction in the cd value hence the load imposed from the or applied on to the transfer to the conduit also will be less.

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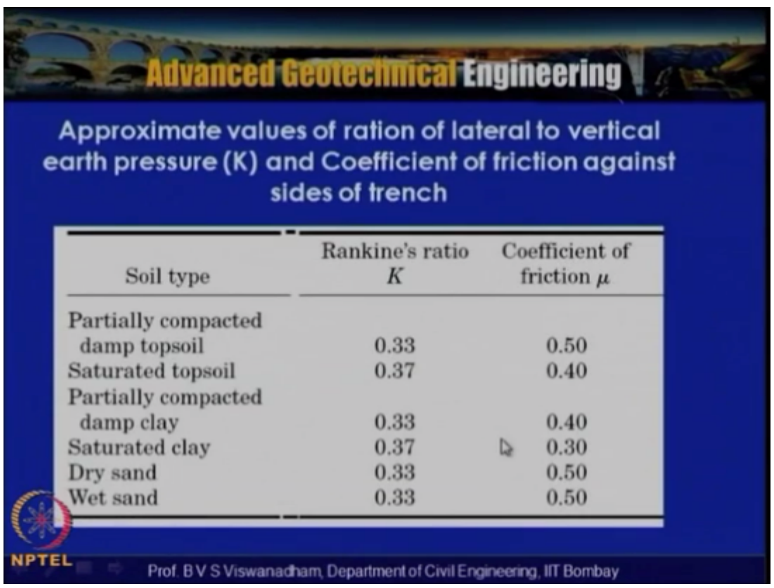

Soil type	Rankine's ratio K	Coefficient of friction μ
Partially compacted damp topsoil	0.33	0.50
Saturated topsoil	0.37	0.40
Partially compacted damp clay	0.33	0.40
Saturated clay	0.37	0.30
Dry sand	0.33	0.50
Wet sand	0.33	0.50

So in this particular slide the approximate values of ratio of lateral to vertical earth pressure k and coefficient of friction again the size of the trench is given and here it is this is the ranking ratio where k which is given as .33 for a partially compacted damp top soil and the coefficient of friction is μ then you know saturated top soil is .37 and the coefficient of friction is .4 the partially compacted damp clay is .33 k value.

And coefficient of friction is .4 the saturated clay is .37 and coefficient of friction is .3 and dry sand it is .33 Rankine's ratio k and coefficient of friction is .5 and wet sand it is .33 and coefficient of friction is .5.

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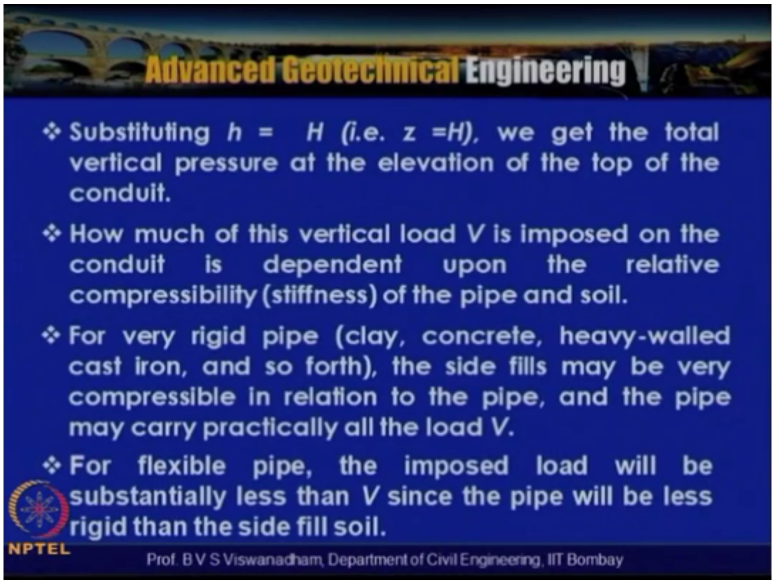

So when you seen is that in the previous equation when v=γcd*bd2 where by substituting for cd expression when h=h or z=h we get the total vertical pressure t the elevation of the top of the conduit now how much of this vertical v load we imposed on the conduit is dependent on the pipe and soil.

So that we have discussed about the different types of the pipes where flexible pipe or rigid pipe or very rigid pipe the clay or concrete or heavy wall cast iron and so for the side fills may be every compressible in relation to the pipe a very rigid pipe that is wet clay or concrete or heavy wall cast iron and so for the side fills may be very compressible in relation to the pipe and the pipe may carry practically all the load that means that most of the rigid pipes the entire load is transfer to the pipes in case of flexible pipes the imposed load in the substantially less than v since the pipe will be less rigid then the side fill soil.

So in case of flexible pipe the imposed load will the substantially less than v since the pipe will be less rigid than the side of the soil so we how much vertical load transferred on to the conduit is depending upon the into compressibility a rigid stiffness of the pipe and the soil that is the pipe soil into stiffness so we have understood now for very rigid pipes.

And the side fills may be very compressible relation to the pipe and the pipe may carry practical on the load and the pipe of arching and type of arching also picture here that passive arching and in case of flexible pipes imposed load in the substantially less than V since the pipe will be less rigid than the side fill soils so that is active arching phenomenon.

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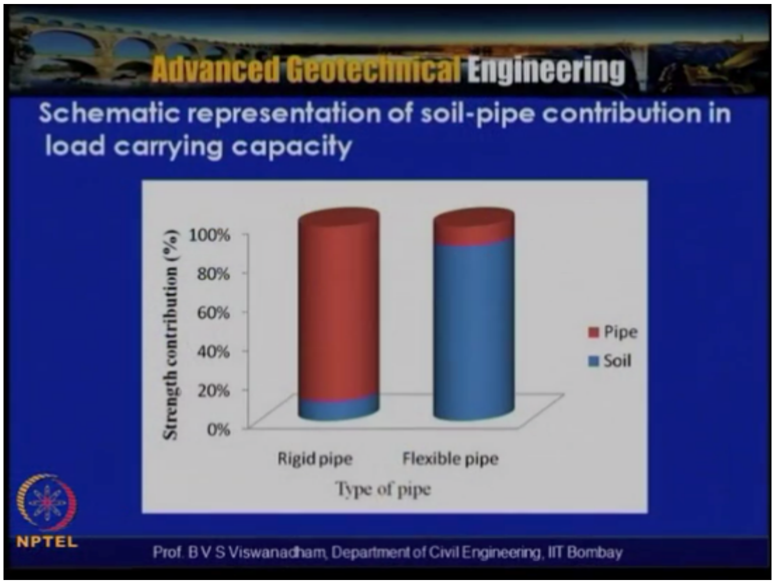

So if you look into this schematic representation of soil pipe contribution in the load carry possibility rigid pipe carries almost you know 80% of the load and only soil carries you know 20% in case of flexible pipe the soil based entire load and only 205 of the load is actually portion by the pipe so the baecuse of the active arching condition what will actually happen is that.

The flexible pipe attracts less load and it actually transfer the load to the surrounding non yielding portions and phenomenon is actually sued in case of a flexible pipes so thi8s particular slide shows the strength contribution percentage in y axis and rigid pipes are flexible pipe the type of this thing so this clearly shows that this pipe and the soil contribution rigid pipe is actually very high the load portioning the capability is very high compare to flexible pipe.

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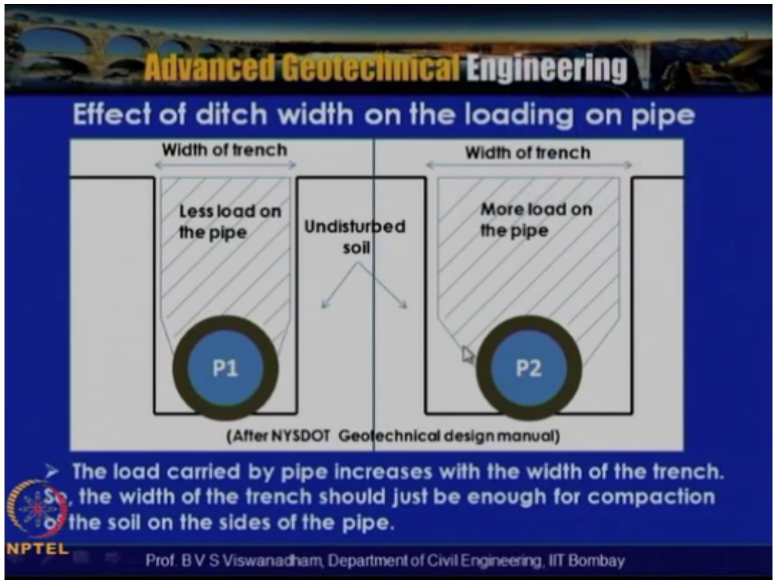

So effective of the ditch width on the loading on the pipe so here the width of the trench and the width of the suppose if you vary shaving you know less width of the trench then the pipe actually attracts less load because of the participation of the trench and if width of the trench is actually more than the load carrying the pipe increases the width of the trench.

So that width of the trench should be just enough for the compaction of the soil on the sides of the pipes so here you know what we have try to understand is that the effect of the ditch width on the lodging on the pipe if you look into it if y6ou are actually having you know the large width of the trench.

There is the possibility that you know the pipe attracts the more load so when we have to be careful in actually selecting the width of the trench such that if it is actually just possible to do the compaction and there should be optimum width of the trench such that the pipe ill not actually attract the more load.

These and all is actually very similar to the you know the slope position technique by suing pipe when we are actually having pipe which are actually space is closer we said that you know the participation of arching is very, very significant when the pipes are actually is spaced or you know spreaded along the slope and which are actually larger spacing then we said that the participation of you know the arching will be very, very less.

So the effect of the ditch width on the loading on the pipe if you are look into the load carried by pipe increases with the width of the trench, so the width of the trench should be just enough for the compaction of the soil on the sides of the pipe and similarly the mod of failure of the flexible pipes if you look into it when well compacted soil promotes good lateral support to the pipes.

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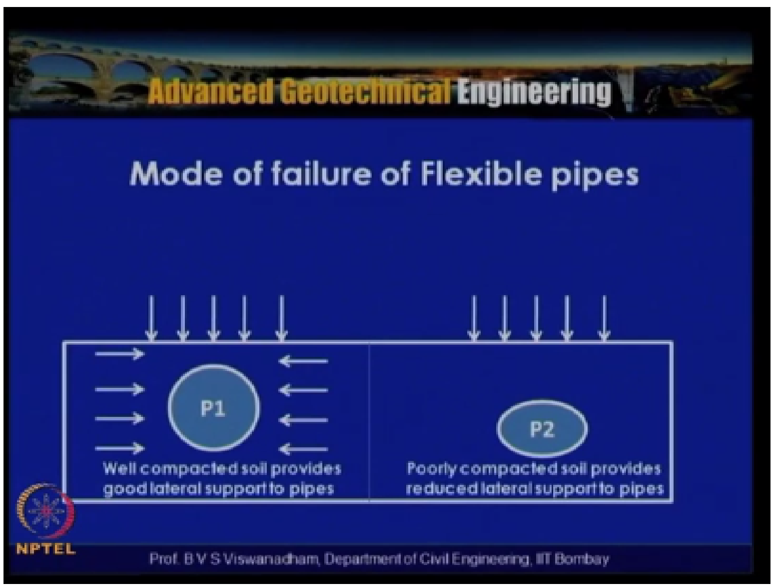

But purely compacted soil provided reduced lateral support to the pipes so the pipe actually undergoes you know the changes in it shapes by particularly for flexible pipes one can see that the pipe undergoes deformations like this the you know the elliptical pipes which will actually take because of the last of the support on the sides, so the pulling compacted soil you know provides reduced lateral support to the pipes, if you are having you know well compacted soil and it provides the good lateral support and the settlements in the within the allow.

You know the 2% of the diameter of the pipe so if you are having a mod of failure of flexible pipe if you look into it the poorly compacted soil produces lateral support to the pipes and because of the loss of the support the pipe actually undergoes changes and you know further increase of any external loading which is actually disusing in the next lecture with that what will happen is that the pipe line actually can undergo distress similarly when you are actually having, having rigid pipes we said that rigid pipes attracting most of the load.

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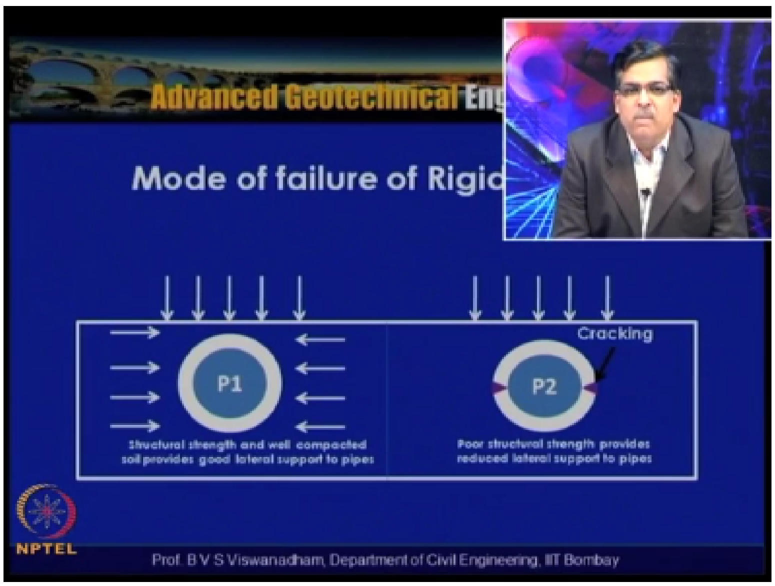

And the structural strength and wall well compacted soil provide good lateral support to the pipe and poor structural strength for example that if the pipe is actually subjected to certain you know the cracking this poor structural strength provides and reduce lateral support to the pipes and the you know the cracking can actually you can and danger the pipe integrating so what we have seen in this particular lecture is that we introduced ourselves to the different conditions on is called the projecting conditions.

One is trench condition or ditch condition then we said that different types of positive projecting positive continues and negative projecting continues and they also discussed about the imperfect projection condition then we also discussed about that we drained to distinguish between rigid pipes and you know flexible pipes and in a way we actually brought active arching and passive arching phenomenon and we said that active arching phenomenon is actually predominant in flexible pipes and passive arching phenomenon is actually prevalent and predominant in rigid pipes.

And then w also discussed about the masters load theory for trench condition that is the ditch condition varying we side that in case of flexible pipe and depending upon the as the stress is actually portion by the side wall friction the load transformation will be reduce and we also said that how the load can be computed by suing v=cd*γ*bd2 and we said that if the breadth of the trench is actually large and then pipe can actually you know attractive more amount of the load.

And then we also have seen finally the different typical board of failures of flexible pipes were flexible pipes really can undergoes large deformations and the deflections are deformations such that the shape of the flexible pipe will actually changed in case of rigid pipes it undergo you know the stress cracking and which actually reduces the cross section because of that what will happen is that they lateral support of the pipe will be lost.

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