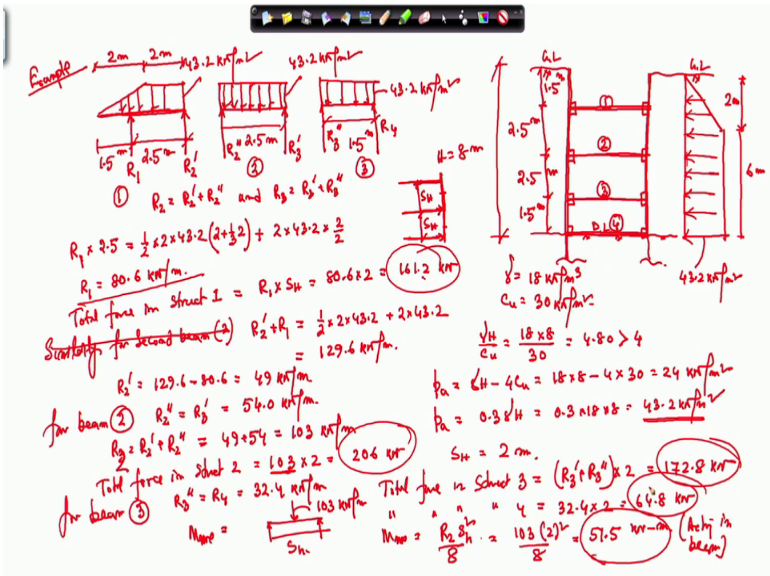
Foundation Engineering
Prof. Kousik Deb
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture – 59
Braced Excavation and Underground Conduits

So, this class first I will discuss that, how we can calculate the start force bending moment in the wall for Braced Excavation then, I will discuss about the Underground Conduit. So, first I am solving one problem related to the braced excavation and I will show you how we can determine the start forces for the braced excavation.

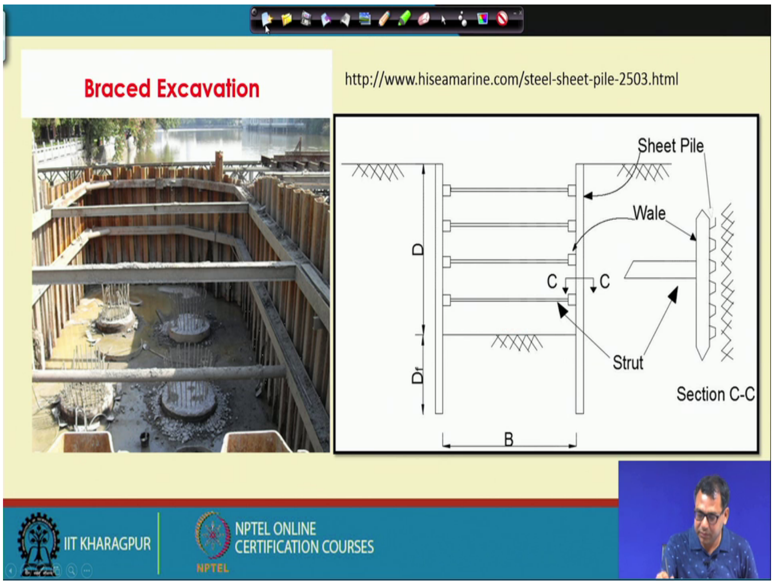
(Refer Slide Time: 00:43)



So, I am taking one problem that this is the wall, sometimes, if it is the permanent structure then this can diaphragm walls are also use for; that means, this can be temporal structure, it can be sheet pile for permanent wall also or permanent structure, it can be the sheet a diaphragm walls or in the sheet pile also ok.

So, this is the braced excavation ground level, this is the wall ok, this is the dredge level. So here, so, these things will continue below the dredge level. So, here I will discuss only the determination of start force, above the dredge level ok. So, this is the dredge level.

(Refer Slide Time: 01:45)

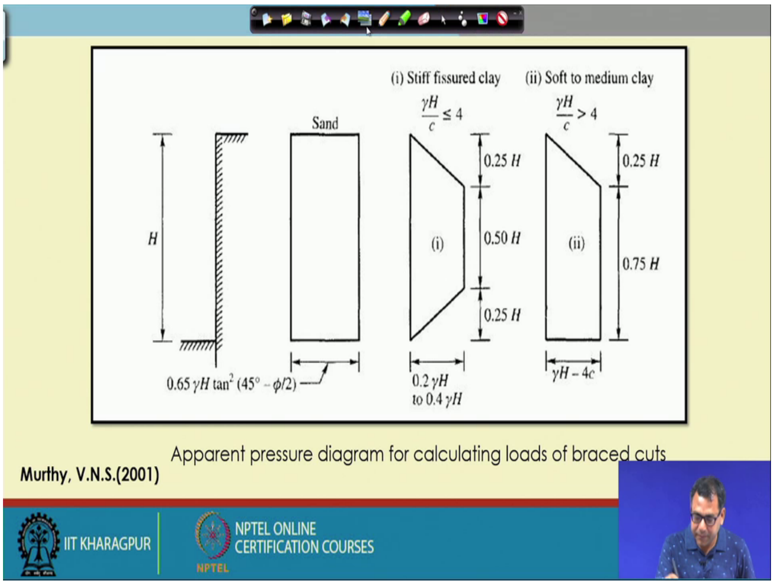


So, you can see the so, here this is the dredge level ok. So, this one is this is the dredge level or here this is the dredge level ok. So, this is the dredge level or here this is the dredge level or the dredge level fine. So, similarly I am also drawing this type of problem. So, this is the ground level and this is the dredge level ok.

Now, we have 4 start system excavation system. So, this is one start this is another start and this is the third start and fourth start is placed as the dredge level ok. So, this is first, second third, fourth, sometimes you cannot place start in the dredge level. So, in that position you have to remove that start, but here this is the fourth start and the spacing vertical spacing is given 1.5 meter the first one, second one is 2.5 meter from the first one and then this is also 2.5 meter and this one again 1.5 meter and the soil properties gamma unit weight is 18 kilo Newton per meter cube and Cu value is equal to 30 kilo Newton per meter square ok.

So, the distribution as I mentioned that, first we have to check that way, what is the value of that gamma H divided by C or Cu. So, gamma is 18 and H value is calculate this H value is 2.5 and then 3 is this is total 8 meter. So, H value is 8 meter. So, this is 18 into 8 divided by 30. So, that equal to 4.8. So, which is greater than 4.

(Refer Slide Time: 04:16)



So, ideally we should use, if it is greater than 4, then you should use this distribution ok, because it is greater than 4, you should use this distribution but this value is 4.8 very close to 4. So, what I will do, I will check both the distribution then, I will decide which one I will use as this value is very close to 4, but as it is close greater than 4. So, theoretically you can directly use that that is not a issue, but I will check that and then I will use based on the values that I will got, I will get ok.

So, the so, first the distribution that, I am checking that my P a is gamma H minus 4 Cu ok. Gamma is 18, H is 8 minus 4 into Cu is 30. So, this is 24 kilo Newton per meter square. So, if it is the third distribution, if I get the another, distribution then my Pa, I am taking 3 gamma H ok. So, this is 0.3 into 8, 18 into 8. So, this is given 43.2 kilo Newton per meter square ok.

So, now this is, 43.2 kilo Newton per meter square, this is 24. So, and this value is this gamma H divided by Cu value is very close to 4. So, I will consider this one ok, but theoretically you can consider 24 also, but as 20 this is 43.2 kilo Newton per meter square, which is greater than 24. So, I am using 43 as the as the your stress distribution, but I will take that your distribution is the fourth one, but the value I am taking the second one, because you can see that my, this is distribution is I am using this one, but value I am taking the second one ok, just clear this thing because as gamma is divided by C is greater than 4, it is 4.8 that is why, I am taking the distribution of the soft medium clay, but value I am taking for stiff clays, because that as it is very close to 4.

But you can consider the distribution of soft clay as well as, you can also consider the 24 kilo Newton per meter square that is also correct ok. So, to be on the safe side, I am considering the 443 point your how much? 43.2 kilo Newton per meter square distribution, udl value pressure value and the distribution I am taking the right one ok. So, clear that.

So, that is why I am so now, ok. So, I will take this distribution and this value is 43.2 kilo Newton per meter square and this is the distribution. So, this one is you know this is the 2 meter, this is H by 4. So, 2 meter and remaining one is 6 meter ok.

So, now what I will do, I will take this, sheet pile and these brace start system and then divide them in small segment and consider that one particular beam. So, this is the particular one small one. So, I am considering this is one beam ok. So, this is the reaction is R 1 and this is R 2 dash. So, this is the first start reaction and this is the beam of this sheet pile and then, I am considering the next one.

So, this is R 2 double dash and R 3 dash, this 3 then the next one, this is R 3 double dash and then this is R 4 and the distribution you can see. So, here your distribution will be something like that here distribution is uniform here, distribution is uniform ok. So, this is 43.2 kilo Newton per meter square. This one is distribution is uniform, this is also 43.2 kilo Newton per meter square here, this is also 43.2 kilo Newton per meter square, but remember that this is 2.5 meter, this is 1.5 meter, because this is 1.5 meter, this is 2.5 meter, but this value is 2 meter ok.

So, the remaining one total is 2.5 plus 1.54. So, this one is also 2 meter and this is 2.5 meter and this is also 1.5 meter. So, depending upon the number of start so, I have taken this small segment. So, this is a distribution this distribution, I am talking about this distribution that, I have divided in number of parts for the simplified analysis, this thing I have done to simplify this analysis as I mention this is a simplified analysis ok, I remember that that your R 2 is R 2 dash plus R 2 double dash and R 3 is R 3 dash plus R 3 double dash ok.

So, now what I will do for the first one. So, the so, the first beam, second beam and the third beam so now, I if I take the first beam then this is R 1 R 1 into I am taking the moment from this point from this R 2 dash point. So, R 1 into 2.5, that will be the total first triangle then the rectangle, triangle one half into 2 into 43.2 lever arm will be 2 meter plus from here this is one third of 2 ok, then plus this rectangle, which is 2 meter into 43.2 and lever arm will be 2 divided by 2 ok. So, if I solve that, I will get R 1 is equal to 80.6 kilo Newton per meter ok.

Now, as I mention that there are two spacing of this start system. So, one is vertical that, I have given horizontal spacing SH was given 2 meter ok. So, the total force this is for the for the 1 start and this is kilo Newton per meter. So, now, the total force in start 1 is equal to R 1 into SH ok. The horizontal spacing so, this will be 8.6 into 2. So, this will be equal to 161.2 kilo Newton.

Similarly, similarly solving the second beam, for second beam or two we will get that after solving that, we will get that R 2. So, from the first beam also that R 2 dash, we will give you that R 2 dash plus R 1 is equal to R 2 dash plus R 1 is the total force, total force is the triangle first half into 2 into 43.2 plus 2 into 43.2 ok. So, that is equal to 129.6 kilo Newton per meter. So, and R 1 is 80. So, R 2 dash is equal to 129.6 minus 80.6. So, this is equal to 49 kilo Newton per meter ok.

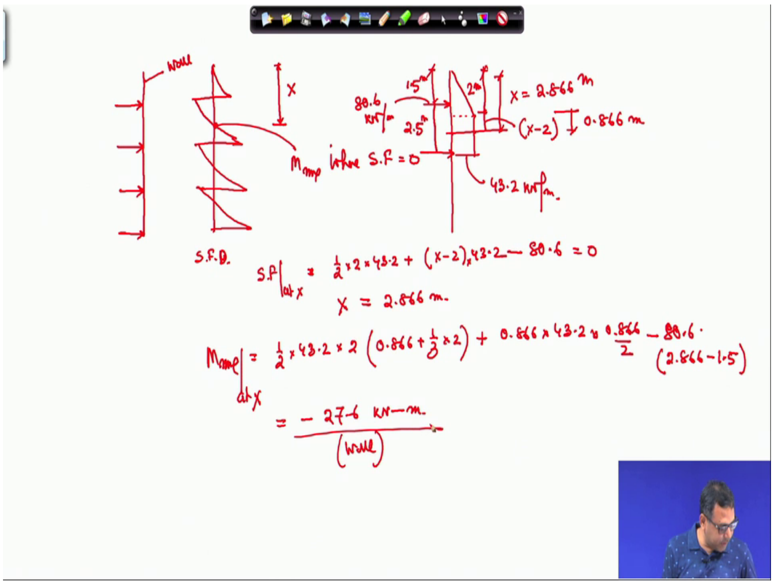
So, similarly from beam 2 so similar way, we can determine that R 2 double dash is equal to R 3 dash, because it is symmetric loading a symmetric is equal to 54.0 kilo Newton per meter. So, my R 3 is equal or R 2 is equal to R 2 dash plus R 2 double dash. So, this is equal to 49 plus 54. So, this will be equal to 103 kilo Newton per meter. So, total force in start 2 will be 123 into 2, that is equal to 206 kilo Newton ok.

Similarly, from beam 3 I can write that R 3 double dash is equal to R 4 is equal to 32.4 kilo Newton per meter. So, the total force in start 3 will be equal to R 3 dash plus R 3 double dash into 2. So, this will be equal to 172.8 kilo Newton, similarly total force in start 4 will be 32.4 into 2, that will be 64.8 kilo Newton.

So, this way we can determine what is the start force acting on the different in the different starts ok. So, this is the total start force. Now what I will do? I will calculate the maximum, because this there is a Euler beam. So, here this is the beam ok. So, here also this is the beam. So, what is the maximum moment acting on this beam? So, here also on this beam I can write the I can assume that on the beam on concentrated load is acting. So, here the maximum concentrated load is acting as this is the load 103 ok.

So, I can write the maximum moment or M max is equal to this is the concentrated load and here this will be the spacing, because if I can write this is the your plan this is the spacing, SH this is the spacing SH and your concentrated load is acting on this is the Euler beam and these are the start ok. So, here the concentrated load is acting. So, here you can see this is the middle and this is the middle. So, I can concentrated load, I assume that one concentrated load is acting which is 103 kilo Newton per meter and this is the SH ok. So, gamma M max will be R 2 S square divided by 8 or SH square ok. So, R 2 103 S is 2 square divided by 8. So, this is 51.5 kilo Newton per meter. So, this is the maximum moment acting in beam or Euler beam.

(Refer Slide Time: 18:18)



So, now I will calculate what is the maximum moment is acting in the start? Now if I consider maximum moment acting in the sheet pile or the wall ok. So, now this is the different start position ok. So, now if I draw the shear force diagram force diagram then the shear force diagram will be something like this ok. So, this is will be the shear force distribution.

So, I want to calculate the maximum force and maximum force will be here, where shear force will be 0, maximum bending moment this is the maximum bending moment, where your SF is equal to 0. So, this is the maximum bending moment point and I say that value is x from this side from the ground level. So, I have to calculate what is the x value? So, x point your shear force is 0, you can see from this diagram ok. So, I can write here at if I draw the distribution that this is 1.5 meter and this one is 2.5 meter and here the distribution is like this and your x value is somewhere in between that this is 2 meter and this value is again 43.2kilo Newton per meter ok.

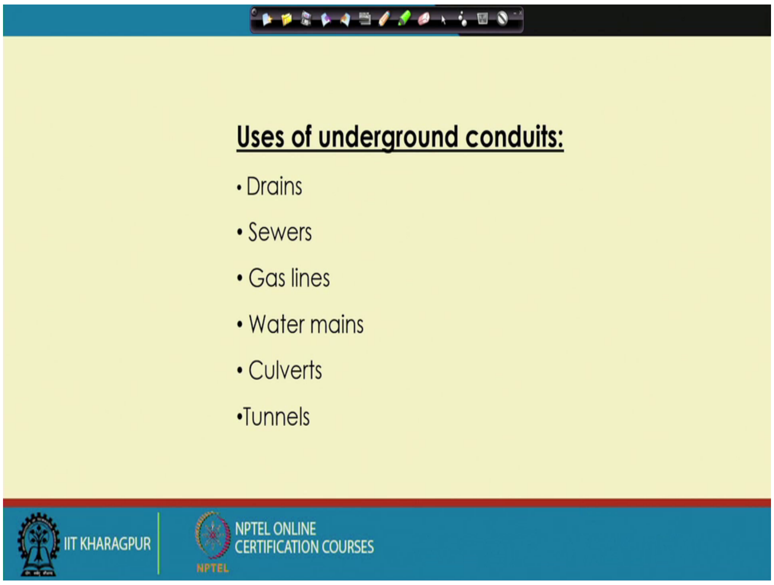
So, now I have to calculate the x value first I will calculate shear force. So, shear force at x. So, shear force at x this is equal to 80.6 kilo Newton ok, that I have already calculated that this is 80.6, the first one the force in first is say, this is the 80 80.6 kilo Newton per meter, this is the R 1 first start. So, similarly this is 80.6 kilo Newton per meter. So, the shear force, shear force at x will be first the triangle, that is half into 2 into 43.2 plus this rectangle, this rectangle is this one is x minus 2, this rectangle, this rectangle, this rectangle will be x minus 2 again, 43.2 then minus, because these things is acting this direction and this force is acting opposite direction. So, this is will be 80.6 that is equal to 0. So, after solving that I can write your x is equal to 2.866 meter.

Now, what is the maximum bending moment? So, here is the maximum bending moment from the x. So, first I will take the triangle. So, triangle is half into 43.2 into the 2 is the height. So, this is the force then the, lever arm will be is equal to your this is 2.866 this is 2. So, this value will be 0.866 meter because this is 2, this one is total x is 2.866 meter. So, this total rectangle portion is 0.866. So, the lever arm from the x, I am taking the moment at x ok. So, lever arm from the x will be 0.866 plus one third into 2 ok, plus the rectangle 1 rectangular 1 will be 0.866 into 43.2 into 0.866 divided by 2, then this force, this force is minus will be 80.6 into this total 12.86 and this one is 1.5. So, this will be 2.866 minus 1.5 ok. So, then in the total moment is coming out to be minus 27.6 kilo Newton per meter.

So, this way we can determine what is the start force is acting? What is the maximum moment in the wall? What is the maximum moment in the beam? So, maximum moment in the wall or the sheet pile is this one maximum moment in the beam is this one and the start forces are. So, total start forces is this one, then 64.38, this value and for 2 this value this is for the first start, second start, third start, fourth start ok. So, this way we can determine the forces and the moments acting in the bracing system ok, but this is a simplified analysis if you want to do the actual analysis, then you have to do or solve it numerically.

So, next one that I will start is the, another topic which is the your, underground conduit and that will be the last topic of this course ok.

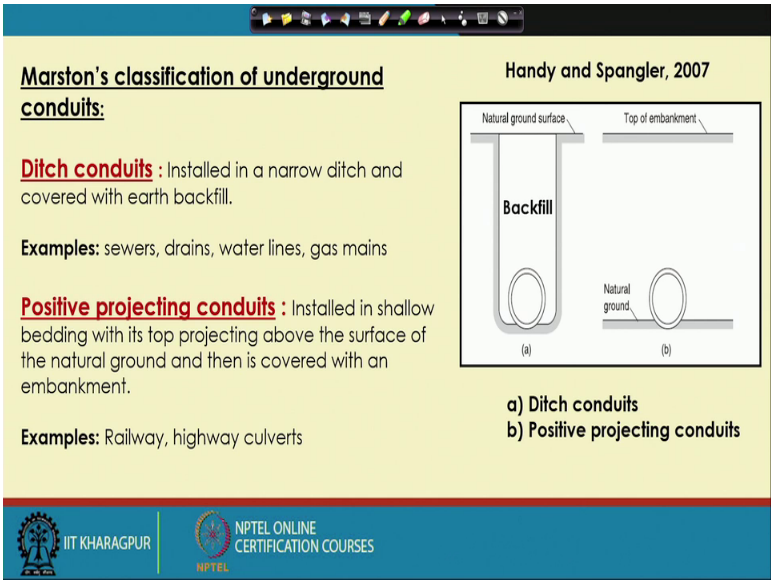
(Refer Slide Time: 24:35)



So, that I will start, I will explain what are the application areas of the underground conduit and what is the load sharing mechanism ok.

So, this is the use of underground conduit. So, what is the underground conduit? So, that can be used in drains, sewers, gas line, water mains, culverts and tunnels these are the application areas and then.

(Refer Slide Time: 24:52)

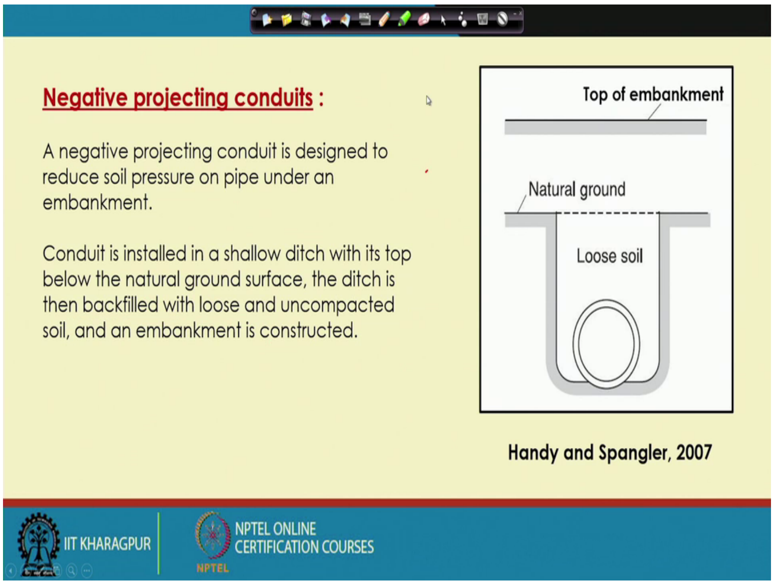


So, classification of the underground conduit so, these are the classification of underground conduit, so first the ditch conduit. So, it is installed in a narrow ditched and covered with earth backfill. So, this is your our natural. So, this is a natural surface. So, it is installed here this is the conduit ok. So, this is the circle 1 is the conduit it can be either tunnel or it can be pipeline ok.

So, this is the conduit, which is install and above that the back filling is done, if this type of conduit is there this is your natural ground surface. So, this conduits is install in a narrow backfill and cover with earth them and remember that, your natural ground surface is above the conduit; that means, one excavation is done on the narrow ditched is constructed then, the conduit is placed and then the back filling is done. So, this type of conduit is called ditch conduit.

Then another, an example areas is drain, water line, gas lines, etcetera. The positive projecting conduits is, this type where this is the natural ground and it is constructed like this and then above that embankment is constructed ok. So, this is example of railway, highway, culvert or tunnels ok. So, this is the second type of conduit.

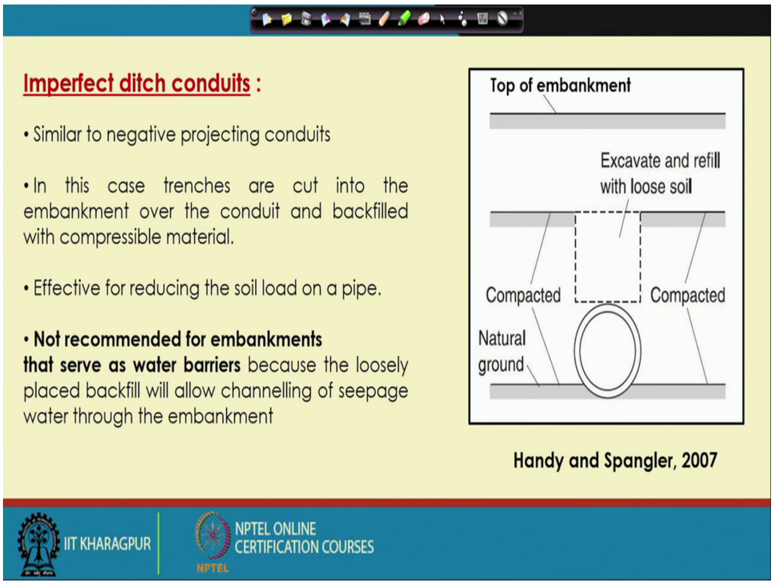
(Refer Slide Time: 26:25)



Then the third type of, the third type of conduit is negative projecting conduit. So, here this is natural ground surface. So, here it is installed below the natural ground surface with some excavation and then this portion is filled with loose soil, then above that the embankment is constructed. So, what is the idea of this loose soil? Because of this loose soil, the stress which is coming on the conduit is reduced. So, it is mention, this and the embankment is constructed. So, to reduce the soil pressure so, so, reduce the soil pressure on pipe under an embankment.

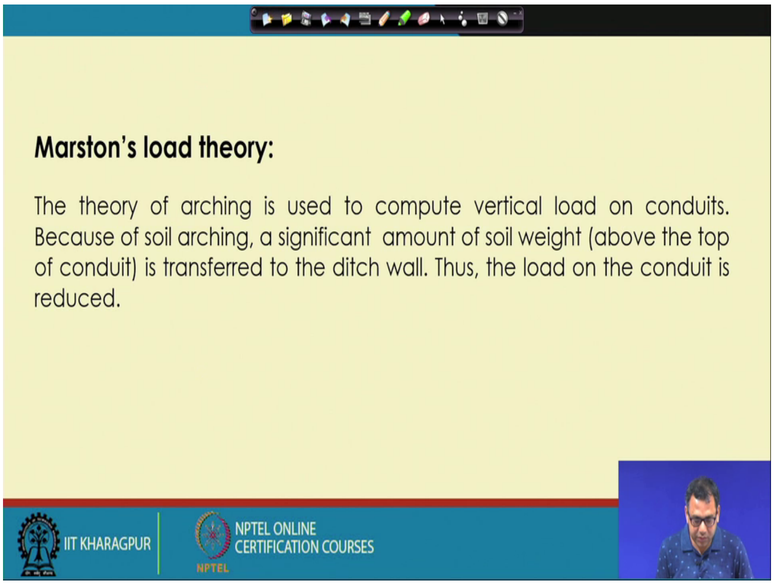
So, I will explain how the soil pressure is reduced under this type of arrangement.

(Refer Slide Time: 27:19)



The fourth one is. The fourth one is the imperfect ditch conduit, which is similar to the negative projecting conduit, but the difference is that this is the natural ground, then excavation is done in the embankment itself. So previous one, you see this is the natural ground an excavation is done below the embark natural ground and the fourth one the excavation is done in the embankment then, where in the loose soil is done? Loose soil is filled or placed to reduce the stress acting on the conduit then, the embankment this is the embankment which is constructed. So, the excavation is done within the embankment and this is not recommended for embankment that serve as water barrier because the loosely placed backfill will allow the water or the seepage through the embankment ok.

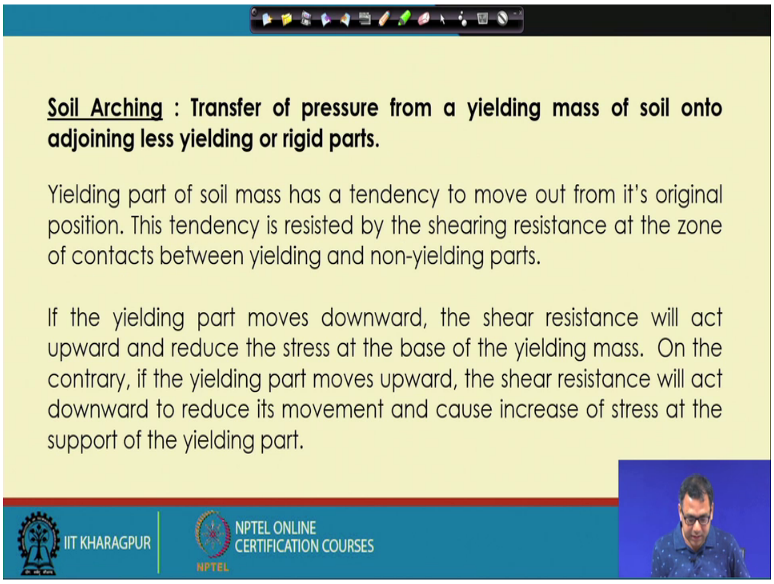
(Refer Slide Time: 28:20)



So, this is the 4 types of conduit. And then, the important thing is the arching or the load theory. So, this theory of arching is used to compute the vertical load on conduit, which is very important. So, because of the soil arching a significant amount of soil weight is transferred to the ditch wall, does the load on the conduit is reduced.

So, let me explain first say suppose this problem we are taking. So, what is soil arching?

(Refer Slide Time: 28:51)



Ok before that the definition is given, what is soil arching? Soil arching is transfer of pressure from the yielding mass of soil onto the adjoining less yielding or rigid part ok. Now this soil arching can be negative soil arching can be positive also.

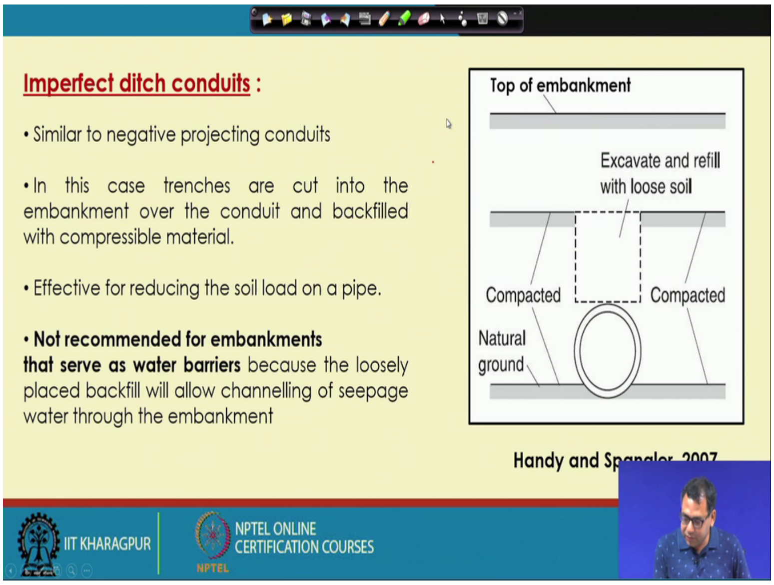
First let me explain what is the meaning of this transfer of stress from yielding mass of soil on to the adjoining less yielding of the rigid part? Ok. So, suppose if we have this type of arrangement ok. Now here, what will happen? That when the your this is the embankment and this is the loose soil. So, this loose soil will deform more compared to this compacted soil or this natural ground, because this is the loose soil, this will deform more ok. So, deformation of this loose soil is more compacted compared to the surrounding soil. So that means, it is a yielding part and this is the less yielding or the rigid part. So, this is the rigid part or this is the yielding or moving part, this is also rigid part. So, what will happen?

So that means, this portion is rigid, this portion is moving, which is deforming or that mean there will be a deformation of this part compared to this one. So, when this soil is deforming and this soil is rigid it is less deform soil. So, a shear plane will develop, this is deforming this downward direction a shear plane is develop at the surface of this yielding and less yielding of the further rigid part. So, this is the shear plane which is developed.

So, this shear plane will allow the stress from this portion to the transfer the stress from this portion to here. So, that is the, it is mention the transfer of stress from yielding part to the less yielding or the rigid part. So, because of the shear plane the stress is transfer from this yielding or moving or deform part to the rigid part.

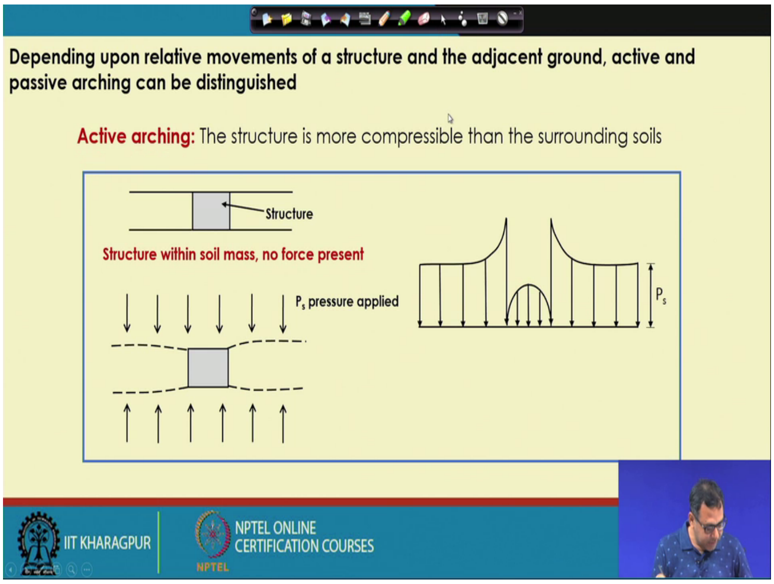
So, the ultimately stress acting on this conduit will be reduced. So, that is called the soil arching. So, arching means the so, it will transfer the stress through from the yielding or the deform part to the less yielding or less deform or the rigid part ok. So, that will help to reduce the stress ok.

(Refer Slide Time: 31:47)



So, now similar thing, we will done here also because, here also it is the loose soil.

(Refer Slide Time: 31:53)

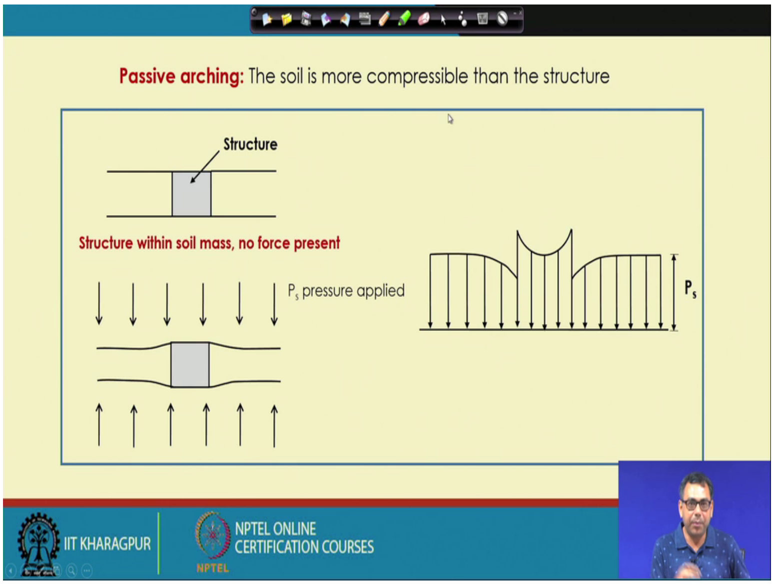


So, now this movement of the part can be 2 types as I mention soil arching can be 2 types, one is the positive, one is the negative. Suppose this is your structure ok. So, this is the structure ok, this portion is the structure here this is the structure. So, this is the structure.

Now, if the structure within the soil mass, when this is the so that means, here we can side the negative or positive or active or passive. So, with the active arching means structure is more compressible than the surrounding soil. So that is the case, I have explained that mean this portion of the soil is deform more compare to the surrounding soil. So, your structure is more deformation of the structure is more compare to the surrounding soil. So, here your structure is yielding part and the surrounding soil is your less yielding or rigid part. So, stress will transfer to the rigid or the soil.

So, you can see the stress on the structure is less though it is if it is the embankment ideally, it should be the uniform distribution of stress on the structure as well as the soil, but because of the soil arching it will not happen. So, as you can see the stress on the structure is less whereas, the stress on the soil is more. So, this is called the active arching.

(Refer Slide Time: 33:31)



Now, if it is opposite then it is called the passive arching, where the soil is more compressible than the structure; that means, soil deformation is more compared to the structural deformation. So, what will happen? Now the stress from the soil will come to the structure ok. So, you can see the stress on the structure is more compared to the stress in the soil. So, this is called the passive arching. So, because of this condition passive arching condition, your stress on the structure will increase or stress on the rigid part here the structure is more less compressible as compared to the soil. So, structure is the rigid part or the less yielding part. So, stress on the structure will increase compared to the soil.

So, in the next class what I will do? I will derive the expression and the or the equation and then, I will explain how these stress transfer is happen from the soil to the structure or structures to the soil. So here, our intention to make this arrangement such that the stress will transfer from the structural part or the conduit part to the soil. So, that the stress on conduit is reduced ok. So, in the next class I will discuss on that part.

Thank you.