Geotechnical Engineering - II

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Lecture No. 36

Sheet Pile Wall Introduction-I

So, far in this course, I have discussed in detail about the shear strength determination of different types of soils. We have talked about direct shear test, vane shear test, triaxial tests of different types from direct shear test what parameters we get, we have analysed them. From triaxial test, what parameters we get we have analysed them in detail, we have discussed about the pore water pressures, how do they develop, what is the importance of pore water pressure parameters?

And how would you utilize these parameters including the shear strength parameters to characterize the soils of different types as an engineering material, how to do engineering on these materials.

And then we switched over to earth pressure theory. So, these were the basics of the Geotechnical Engineering II course. These are the basics of the materials like soils of different types. And what we have learned so far is how to understand their basic characteristics, how do they perform under different types of drainage conditions and loading conditions. Once we have studied all these things, the issue is where you are going to apply this knowledge.

So, one part of the application of shear strength theory was Earth pressure theory, which we discussed quite in details, and there we talked about different types of retaining walls, how earth pressure gets mobilized on them, we talked about mostly backfills with granular material and then a little bit on how to retain cohesive soil mass as a backfill material with a caution that cohesive material should not be utilized as a backfill material. So, we did all these analyses.

Now, I am switching over from the basic concepts to the application part of Geotechnical Engineering II or you may say this is how the practicing engineers would be using the concepts which have been laid down for understanding and basic characterization of the soil mass, engineering characterization.

So, let me introduce now the concept of sheet piles and these are sheet pile walls. Now, you must have noticed that, in the practice of geotechnical engineering there are several situations where right of way or the right of property or the property line becomes a very big issue. So, far what we have done is we have studied retaining walls and these were mostly gravity retaining walls why gravity because the cross sections were very thick the self-weight is itself was good enough to negotiate with the pressures which are going to come on the walls.

So, what we did is we took heavy sections this is how we designed a RE wall or retaining wall on which the earth pressure is coming. So, many times as I said it is not possible to afford the luxury of space. So, what would you like to do but you still want to create a retention of the geo material. So, under these circumstances, what we can do is, we can switch over from gravity retaining walls which are basically rigid structures to flexible structures. And these flexible structures are also capable of retaining soil for retention of earth or soil, this could also be water, this could also be gas or any sort of liquid, chemicals.

So, the tanks which you see big, big tanks where the petroleum is stored, they are also made up of thin sheets of steel. Truly speaking, each element itself behaves like a sheet pile. So, when we talk about the flexible structures by definition opposite to a rigid gravity structure where the base weights are extremely high. Very, very high. These structures have very thin cross sections.

So, in the process I can save this much amount of the space which is required if I consider this as a half of the retaining wall for construction purpose. So, a thumb rule says if the height of the retaining wall is about H, the base width would be approximately 0.7 H. Now, I think you can realize if you are creating a 10m high wall for retaining the soil mass, if you remember the backfill, we have stored over here or we have so, this was the ground level this is the backfill material.

So, suppose if H=10m, the base width would be about 7m. So, everywhere you cannot afford this type of a system gravity system apart from it requires too much volume of the concrete, masonry or any compacted material. So, under these circumstances we go for a flexible structure for retention of earth, soil mass, water, gas. It could be any food grain also for that matter why not.

So, depending upon what is that you are storing a sheet pile system can be designed. So, as a geotechnical engineer most of the time we deal with retention of earth, soil mass, water with very thin cross sections as the elements.

So, suppose if somebody asks you a question there is a ground surface like this, and this fellow wants to construct a farmhouse which is elevated. So, he says that I do not want to live over here, I want a sort of some height to be created over here. So, basically, he wants to create, or she wants to create a facility over here.

So, the first question is how you do this on piece of paper, I could do it very easily, but how to do in practice. So, the best way to do in the practice is take these flexible structures which are retaining the material which are thin in cross section, and you insert them over here and then what I can do is I can fill up on the right-hand side soil mass, compact it.

By control compaction you have studied how to check the compaction of the soil in layers. Make it as a platform. So, this platform once it gets created of height H becomes a sheet pile wall because this happens to be a sheet pile, look at the beauty. I could have done the same thing by creating a retaining wall over here. So, if I would have done a retaining wall here, how much space would have been eaten up? So much, correct?

So, I get the same advantage of creating a retained soil mass on which I can Create a facility just by using thin sections and hence the space can be optimized. Now, I can realize that what is the application of this type of construction in metros where the space is a luxury is very expensive, getting materials to make a retention system is extremely difficult this idea seems to be workable.

And I am sure the concepts of mechanics will tell you that this is a system which is very easy to analyse as well. So, what you are doing is you are using the concept of embedment of an element into the soil mass. So, this is the soil mass and trying to retain a bulkhead in technical terms, this is defined as bulkhead. What is bulkhead? Bulk is the bulk of the material volume of the material and head is that you have created a certain height. So, this becomes a bulkhead.

So, in retaining walls we used to use the word backfills which is retained by the retaining wall when we adopt sheet pile the terminology is bulkhead or the soil mass which is being filled up over here. This could be water also. So, this is one of the facilities which I have created, I have created elevated bulkhead for developing a property. There could be a different situation also, there could be a situation where I want to create a basement let us say.

A city like Bombay. You know most of the infrastructure requires parking lots or some facilities underground facility. Let us say a cancer treatment facility in a hospital where you do not want to expose the X-rays or different type of isotopes, which you are using on the patients and to the atmosphere. So, these types of facilities are normally concealed they are underground.

So, suppose if I want to construct the underground system, I could have used the retaining wall also there, but then as I said these are the negative aspects, the best thing would be using the sheet pile and what can be done? I can start excavating over here. So, if I start excavating, I can remove this soil mass and I can create a facility over here. So, this material can be removed.

And in other words, what I have done? I have created an underground facility. So, this becomes an underground facility. Is this, ok? Which is nothing but a basement. So, now, we are realizing we are the master of the subject, we are trying to use the concepts in such a manner that I can create any structure, I can create any facility if I remember the concepts of stress paths, as you did after triaxial testing, how would you use the concept of triaxial testing here the stress paths.

So, go back to the basics take a point at the depth of z and define the state of stress. I can do the same thing over here also. This point and I would like to find out the state of stress at point 1 and at point number 2. So, if this is σ_v, σ_h same thing is acting over here σ_v, σ_h, what are the difference between the two situations.

In this case, $\Delta\sigma > 0$, loading case. Correct? Now, $\Delta\sigma_h$ could be whatever. We have solved these types of problems. We have defined the stress paths for this condition. Starting from a hydrostatic condition or from a different initial condition. If I construct a facility, I know how much the height of this is, I know the unit weight, I know what the delta sigma v value is, $\Delta\sigma_h$ may be 0, it could be positive, it could be negative also, depending upon how you are using this space.

In this situation, what is happening? When I am removing the material, $\Delta\sigma_v$ becomes negative removal. So, remember we talked about these conditions in the stress paths. Active earth pressure, passive earth pressure, loading and unloading, we had drawn this long back, so, please go back and check those lectures again.

So, coming back to the point these thin elements are becoming very useful for construction of infrastructure mostly in soft soils. But please remember one thing in case of soft soils, these structures are not going to be permanent, they are only going to be temporary. So, they are basically made for temporary retention of soil mass that too not of very big heights not very large heights.

So, heights will be roughly 3 to 5 meters not more than that, but they are very useful for granular materials and then we can design a system in such a manner that I can achieve a certain height. Now, you can realize intentionally I did not talk about anything which is beneath the ground. But your concepts of Engineering Mechanics and Solid Mechanics and Basic Structural Engineering will tell you that this is what is going to give you the embedment and this embedment also mobilizes the moments.

So, if you now start putting the mechanics here, what you will realize is this portion which is hanging up the ground surface would have a tendency to deflect on the left-hand side, why? Because the simple logic says that this is the bulkhead which I have created is going to be under active earth pressure condition. So, it is going to apply active earth pressure.

Now, we will further discuss this later, but anyway just for a quick discussion, the embedment is going to come from the resistance which is being offered by the soil mass on the left-hand side. So, the way I have shown an excavation if you do it like this, I am sure your retaining wall is going to fail. Now, this is where we have to apply the concept of optimization of the excavation from the face of the retaining wall. That means there has to be a distance up to which this wall is going to be stable.

That means, this much of the soil mass which I have created is going to apply a passive earth pressure on the retaining wall. So, truly speaking, these flexible units which we have inserted into the ground for creating retention or creating excavation, they are known as sheet piles,

why wall? Because these are the walls made up of the sheets and they run in several meters or hundreds of meters or tens of meters depending upon your requirement.

So, now you can visualize in the 3d. So, these walls will be running up to certain length as far as the property line is concerned. And what we are doing is we are utilizing the concept of active and passive earth pressures to analyse the system and of course, the stress paths because without stress path, we cannot compute the incremental changes in the active and passive earth pressures. So, all these basics we have discussed in the class.

Now, what you require is the material property the moment the c, ϕ, γ, drainage conditions, submergence conditions, you can compute P_a, P_p. We have done enough analysis the whole aim is to find out d so, that I can say the total height of the wall is equal to H plus some factors let us say m times d, so this is some factor which we will be discussing later on. So, these are basic concepts.

Another example you might be doing you might have observed, trenching operations falling the pipelines. So, this is the ground and normally these pipelines which are carrying water or hydrocarbons, petroleum, they are normally buried up to a depth of 3 and a half to 5 meters because of different reasons. Number 1 to stop any type of burglary, tapping of fluids, unauthenticated.

So, suppose if I want to lay a pipeline over here, how would I do this? You have to do a trenching operation. Now, trenching means you have to remove this material. We studied the concept of z_{cr} you remember what is z_{cr}? The height of vertical cut in a c-ϕ soil. So, this is the unsupported height of vertical cut. So, this we have studied already.

The idea is if I am going beyond if $z > z_{cr}$ what it corresponds to? This corresponds that you require some additional protection or support so, that the trench remains stable otherwise what will happen because of the earth pressure the trench will cave in. So, this part also I am going to discuss in subsequent lectures, where I will be talking about why bracings are required by supports are required, what is the concept of slurry trenches? And how to make the trenches stable. This will follow subsequently, another application of shear strength theory.

So, I am sure you must be realizing that there are a lot of applications of shear strength theory. So, those of you who are under the impression that this course is only conceptual or theoretical, I am sure that you must be realizing now this is becoming more and more practical now, you can create a situation using the concepts which you have studied so far you can apply them, and you can create a system, infrastructure.

So, coming back to this point, the best thing would be if this is the situation and you want to stop caving in what I should be doing? The best way would be if this is the ground surface you drive in sheets, sheet piles and this much and remove the soil mass and then find out where should I lay the pipeline or any utility for that matter fibre optic cables, underground pipelines. Yeah, drilling wells, so, then you have to go much deeper much, much deeper correct. There could be any application for that matter, what you have to do is use the same concepts.

Now, these piles or these flexible structures or the elements are made up of different types of materials. The type of materials or the materials used could be, materials used for making sheet piles. So, typically, these are of stainless steel with a very sharp cutting edge. So, I will show you some videos today. So, suppose if this is a thin element and if I make a very sharp cutting edge over here, this becomes a typical sheet pile. So, what I have to do?

Keeping in view the stiffness of this element, I can push this element or the sheet pile inside the ground and this becomes a system like this. This is the art of installation of sheet piles. And we are lucky that nowadays there are many specialized companies who are doing this work. Design part you can take care of, analysis part you can take care of, execution part can be done by these companies, their expertise.

These could be also made up of timber or wood. You must have seen in old constructions, people use wooden logs, a beautiful example of this would be dolphins. The dolphins are the type of structure which are used for offshore structures. So, stainless steel can be used, timber wood can be used it could be a composite material also.

Nowadays, we have so, many types of composites, they can be used, PVC can be used particularly for the landfills, a big problem with the landfills is, if there is a landfill a lot of leachates come out so, leachates are the chemical species which drain out or which come out of the landfills because of the percolation or rainfall.

So, suppose there is a facility like this, and I do not want the leachates to spread out into the geo-environment, because most of time there will be a water table here. I hope you can realize the moment is leachates seep down into the soil mass they will have a tendency to pollute the water table and the water table will be moving type we have done this in hydraulic conductivity when you are discussing what the permeability of the soil mass, second fifth sixth lecture of Geotechnical Engineering-I where we were talking about the hydraulic conductivity.

So, if you have a moving or flowing water table this situation is going to be extremely hazardous. What should we do then? Contain the leachates migrating out. The simple example would be, or simple solution would be insert sheet piles and in plan how it is going to look like? it is going to look like a big space which you have created.

So, I have created a confinement again by using small, small segments of the sheet pile. So, you might be having the segments of let us say 2 to 3 meters wide and normally the lengths are about 5 to 7 to 10 meters depending upon the material which you are using, I can put them together and I can create a cofferdam. Is this part, ok?

So, this is the design aspect how we are going to use the basic elements and the concepts of Geotechnical Engineering to create a retention system. So, these types of joints are specially provided by the manufacturers and then you can easily create such type of systems which are almost watertight. So, this is something which is latest in the Geotechnical Engineering application where the landfills are also being contained by using PVC sheet piles, this becomes a typical cofferdam.

So, cofferdams are normally a type of structure, which are created for doing offshore related construction, where you want to divert the flow of water, or you want to create a space which is free of water.

So, suppose if there is a river which is flowing. This is the river; this is the riverbed and I want to construct a bridge over here. So, for constructing the bridges, we need the piers also these are supports now where they are going to sit, they are going to sit somewhere over here. So, this becomes the foundation, how to create this foundation on blackboard or on piece of paper is very easy to do.

But suppose you are doing it in the real system where the soil is somewhere here let us say. It could we rock also, what we will do is? We will create a coffer facility somewhere like this. So, it resembles the situation what I have created over here. So, once you create a space, drain out the water from here by using pumping or say pump out the water, and then this becomes a space where you can work.

So, most of the bridges in the terrain where rivers are flowing, they are constructed like this by creating a coffer dam diversion of water, I am diverting the water creating a space which is free of water, and I can work over there. So, I am sure you must realize that there are lot of applications of simple concepts of Geotechnical Engineering, starting from this to that end.

So, depending upon the materials, which are used for making sheet piles, the design will get changed, their cross sections will be different, the methodology of installation would be different. So, truly speaking sheet piles are classified based on what is the function they are going to perform. Retention of what different types of materials.

So, this is based on what is that you are trying to retain, this is the classification based on the type of material which is used. You must have noticed that in villages particularly in parts of Rajasthan and other areas, where stone is freely available, what they do? They make slabs of stones, and they insert them into the ground. So, this could be made up of stones also.

Stones, slabs big rock mass they will cut in small, small pieces where they become slabs and these slabs are inserted into the soil mass. So, I think this is what the basics are. Sorry, it could be a concrete also, yes very right. So, this could be made up of concrete also. Yes. So, here you can put one more category as concrete. True. Thank you.